Environmental issues in Western Australia

Harry Recher (Ed.)

ECU
EDITH COWAN UNIVERSITY

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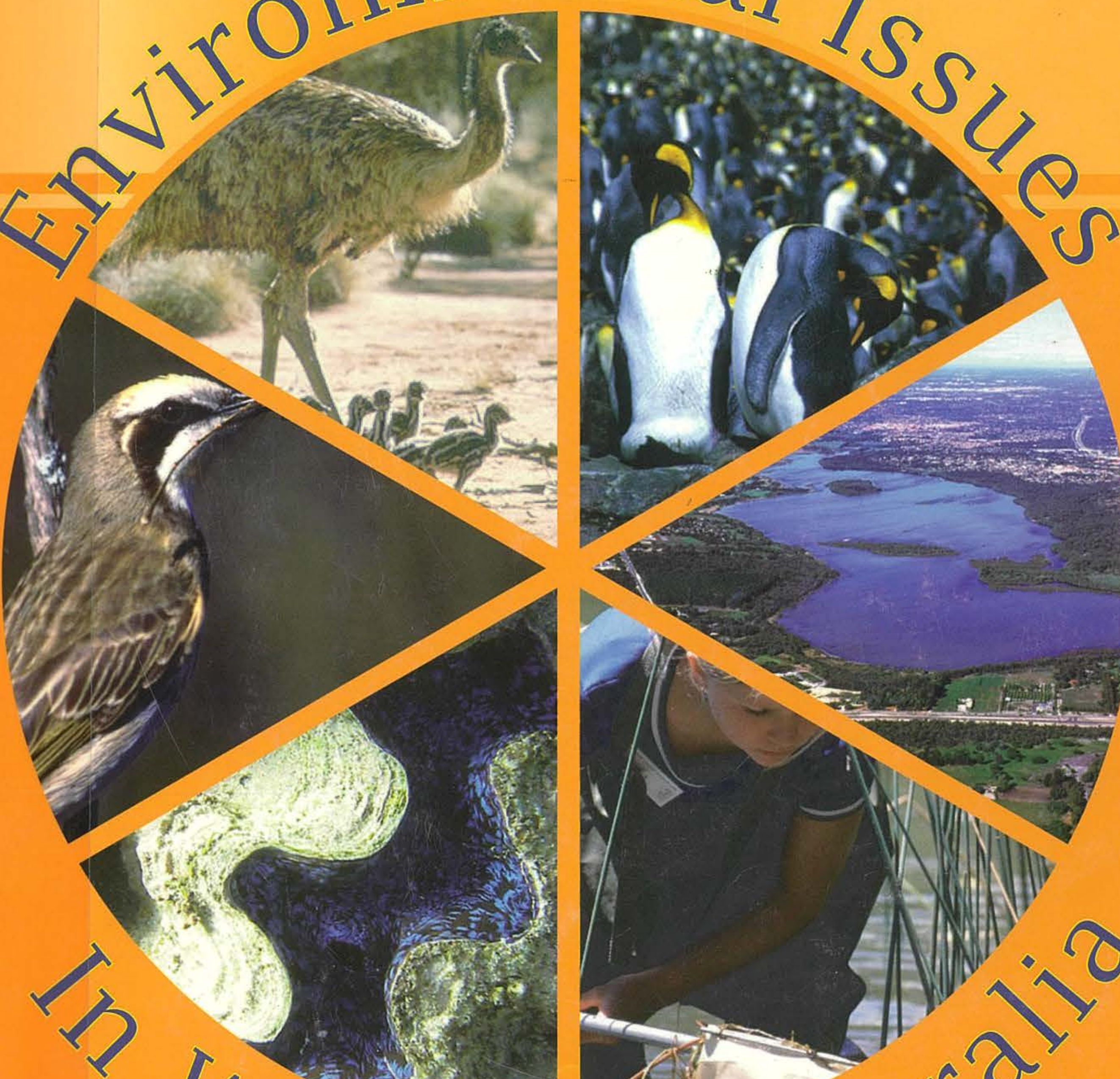

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Environmental Issues In Western Australia

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ECU's Commitment To Our Environment and Future Generations

Edith Cowan University is committed to an environmentally sustainable future. We are concerned about providing a world for future generations and this is reflected in our behaviour and through our courses and research.

In 2002, ECU launched its environmental declaration, which commits the University to sustainable development that meets the needs of the present without compromising the ability of future generations to meet their needs. Of course, there are limits to the difference one individual or one institution can make. However, ECU recognises the important role universities must play in achieving sustainable societies. Universities are often leaders in social policy, adopting policies and procedures long before they become standard practice within main-stream society.

At ECU we take our leadership role in sustainability seriously. In keeping with that philosophy, the University's new Science and Health building was built to groundbreaking environmental standards and won the WA Architecture Awards for environmental efficiency. Recently ECU introduced a comprehensive recycling strategy and has developed a transport action plan to encourage more sustainable transport use practices among staff and students.

Most importantly, ECU graduates take this attitude of leadership in environmentally sustainable behaviour into the broader community, where they can make a real difference.

ECU offers undergraduate courses that provide students the background they need to manage our environment sustainably. Our Environmental Management course gives students an understanding of the environment, and the knowledge and skills used in its management. The strong management focus of this course prepares graduates for careers in government and industry. There are also courses in Biological Sciences, Chemistry and Public Health that all deal with issues related to the conservation of our environment and the wellbeing of people within their environment. Details on these courses can be found at www.ecugreatcareers.com(.)

ECU's Centre for Ecosystem Management undertakes applied research that makes a real difference to how we manage our environment. The Centre brings together a broad range of environmental knowledge and skills that provides practical and appropriate solutions to environmental problems. Like our graduates, the Centre demonstrates a commitment to the maintenance of biodiversity and the improvement of life through appropriate environmental management. Full details of the Centre and its current research activities can be found at www.cem.ecu.edu.au(.)

Sections of this book can be downloaded as pdf files from the School of Natural Sciences webpage: www.chs.ecu.edu.au/org/sons/

About This Book

The last half of the 20th Century witnessed growing concern and interest in our environment. In response, government and industry alike adopted procedures and standards intended to protect and improve the quality of air, water and land for all Australians now and in the future. To conserve and enhance the natural environment, the nation's system of national parks and other conservation reserves was increased by more than threefold and programmes to protect rare and endangered plants and animals were put in place.

Despite these efforts, environmental conservation and management was not always successful and sometimes failed to meet community expectations. A result was conflict and debate over issues as diverse as logging native forests, improving public transport and mining uranium. With all the conflict, it is possible to look back and be thankful for the efforts made to protect Australia's environment and preserve its flora and fauna. Forest logging and uranium mining remain controversial, while debate continues on the merits of new highways versus buses and trains. Other issues, little discussed in the past, have acquired notoriety and demand media attention. Today, Australians confront problems of global warming, declining fisheries and salt affected land and rivers. Managing water so that it is available for people to use while maintaining the quality of inland and coastal waters has captured the media spotlight as drought grips most of the continent.

As daunting as all these environmental challenges appear, there is every prospect that they can be managed and, where needed, environmental quality restored. Australia is fortunate in having a good understanding of the continent's natural processes and a scientific and technical workforce skilled in environmental management. One of the great achievements of the 20th Century was the growth of conservation and environmental management as core businesses of government and industry.








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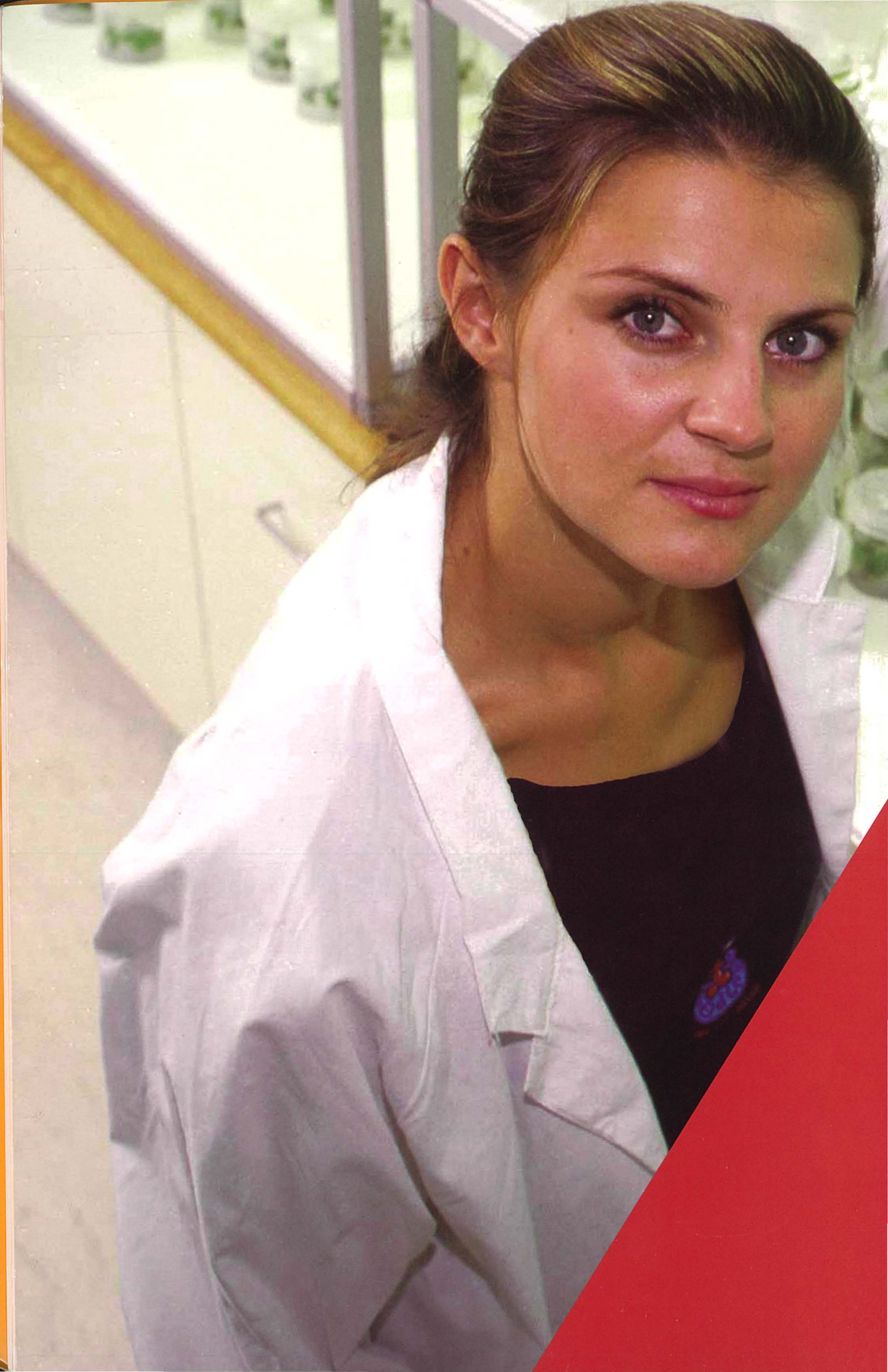


How To Make A Scientist

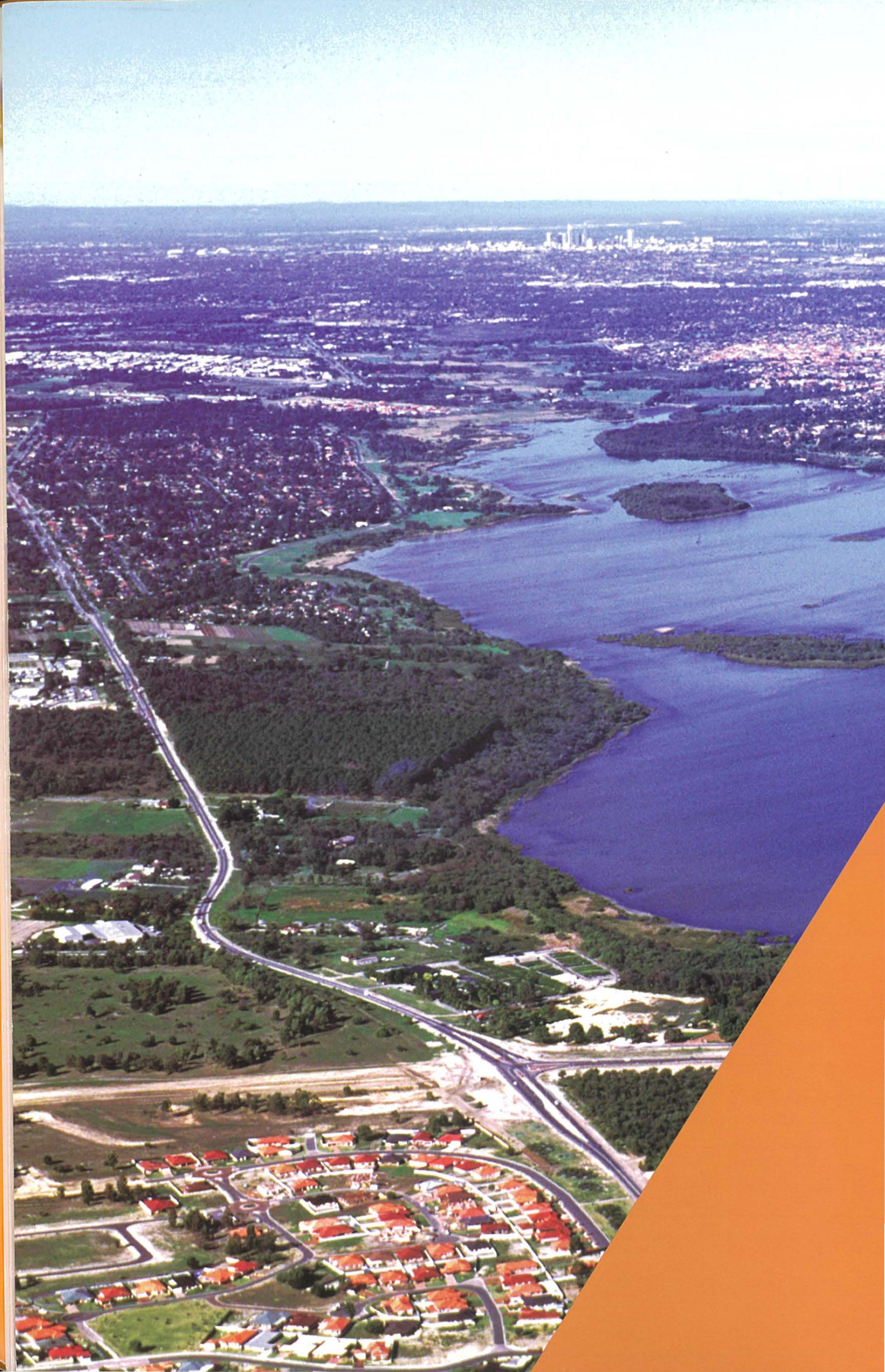
Melinda Hillery

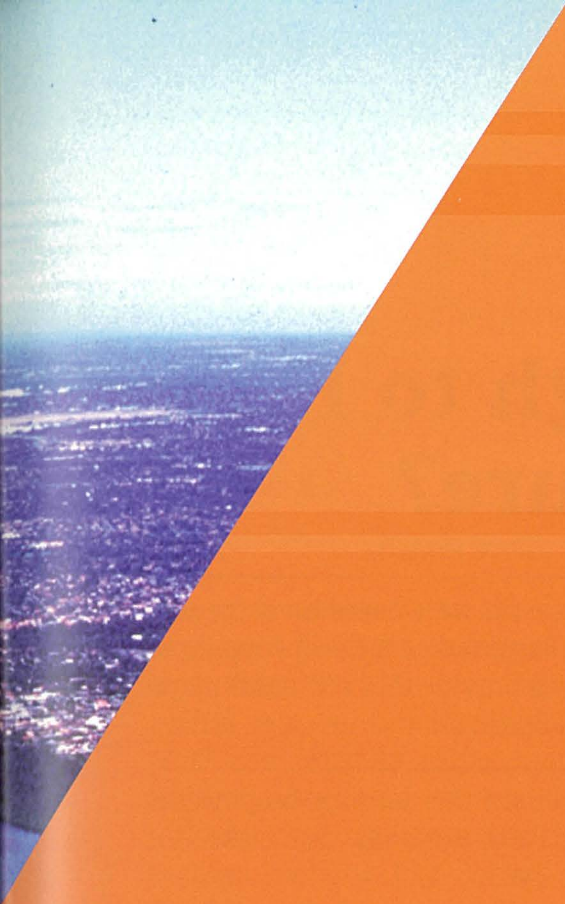
A few people are lucky enough to grow up knowing exactly what they want to do. That wasn't the case for me, and there's a good chance it isn't for you. It certainly seems like a big decision. But don't worry — it turns out that there's plenty of time to change your mind and lots of options you didn't think about in the beginning. That's the great thing about a career in science.

I first got interested in ecology at uni because it gave me the opportunity to go on field trips out in the bush with friends. I like being active and outdoors, but I also like to have something to think about. It seemed that every time I took a new subject I started seeing the world with new eyes. And by doing volunteer work I got to see and do things I would never have dreamed of.

A career in science is about having lots of options and opportunities. Depending on choices I made at different times, I could have become a mining geologist, a teacher, an environmental lawyer, an entomologist (studying insects), or an evolutionary biologist working in a museum. I have worked in environments from old growth forests to deserts. I've travelled through Australia and Africa, visiting other researchers and seeing beautiful places and amazing animals up close.

Now I've taken another turn. In my current job I'm working with people living on the south coast of Western Australia - farmers, fishing people, tour operators, local council staff - to work out how the health of the environment and the health of people are connected. So there are growing opportunities to work for community change in science too. And that's only the beginning. I couldn't have imagined I'd be here ten years ago when I left school, and who knows where I'll be in another ten. Studying ecology in cyberspace?





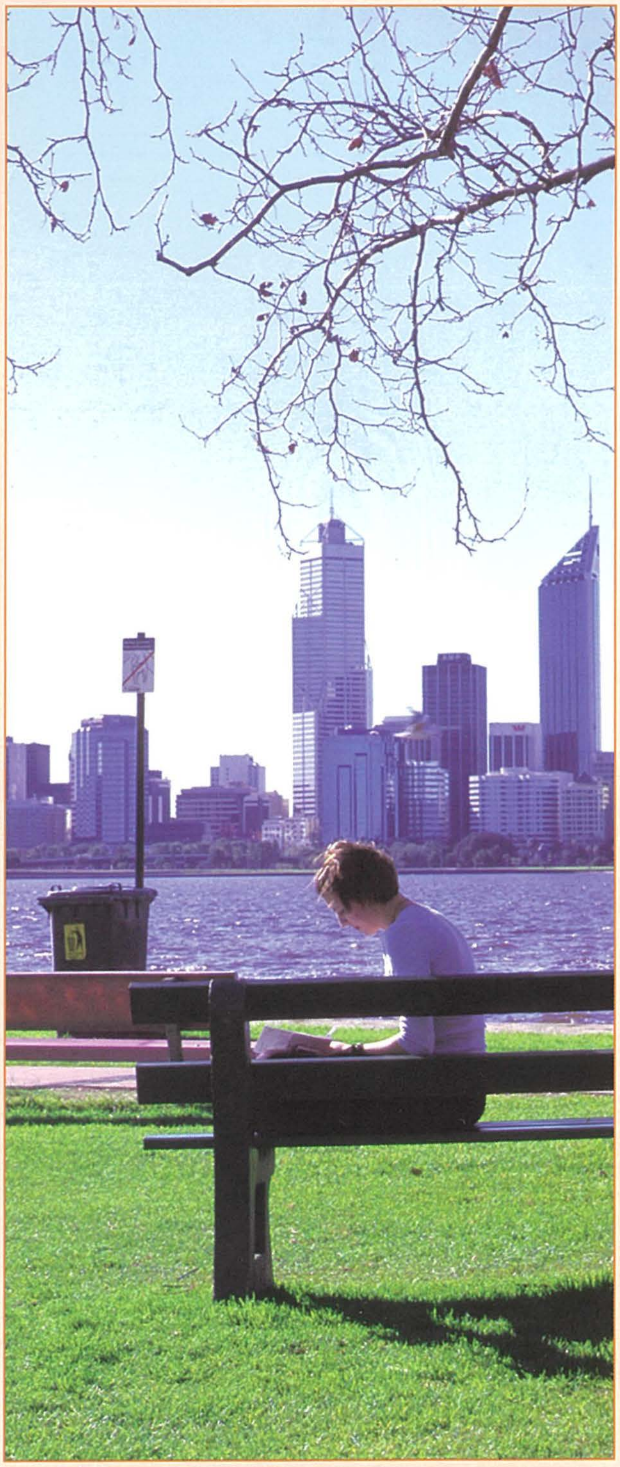
An Urban World

Harry Recher

More than 80 percent of Australians live in large cities or towns. Even in Western Australia, with its vast open expanses, most of us live in Perth. Being city dwellers has its advantages, but so many people living and working in a small space also creates problems. Providing the things people need to live - food and water to mention just two of the most obvious - requires a large transport network of planes, trains, buses, trucks, boats and cars. Energy is expended moving things and people around, pumping water, heating and cooling houses and offices, building homes and factories, providing entertainment and then cleaning up after ourselves. A city becomes a hugely complex and diverse ecosystem with an important difference from more natural environments: energy, water and resources enter and leave the ecosystem without being recycled as happens in forests, oceans and deserts. Unless managed properly, this one-way flow of energy and resources causes pollution of land, air and water. Perth is not immune to pollution - we are all aware of the efforts to 'clean-up' the Swan and Canning Rivers and the unpleasant haze that hangs over the city on cold winter mornings - and learning to manage environmental quality in the urban environment is at the core of the work and studies undertaken by staff and students in Environmental Management at Edith Cowan University. Not all urban problems relate to pollution, many concern the way people interact with the plants and animals that share our city and its suburbs. Insects can be pests, while birds bring pleasure, and managing both in the urban environment is as much the responsibility of environmental scientists as is keeping our waterways and air clean. For this reason, studies of insects, plants and birds, among other wildlife, feature in the urban studies on the Joondalup Campus of ECU.

Are We Clever Enough to Plan For Perth's Future?

Pierre Horwitz



If planning processes were based on some sort of vision, I wonder whether the following three statements would provide that vision for many people living in Perth:

1 We wish to retain the defining biophysical features of the Perth environs that make it a special place to live.

2 We wish to give future generations of Perth more choices in planning, not less choice.

3 We want our future generations to be at least as healthy as we have been.

All three statements depend on planning and a clear understanding of the ecological features that make Perth special. This requires an exploration of Perth's geological, biological, climatic, geographical, and sociohistorical context. It also requires an understanding of how to manage environmental change, and how we can adapt to changes we bring on this continent, without seriously affecting the quality of life of Perth's inhabitants. My argument places ecology at the centre of the planning process. Our impact on south-western Australia significantly affects the quality of life in Perth and planning for Perth cannot be done without examining the "ecological footprint" of Perth's inhabitants. We will always need to provide for ourselves from our local and regional environment, but we need to recognise that our behaviour places a significant ecological demand on our environment.

On a positive note, there are aspects of the way Perth has been planned, which deserve to be held up as beacons of reasoning by our forebears and as a guide for the future. One of them is Kings Park, the other is the relative lack of development on the foreshore of our beaches. A generous reading of Perth's history sees Kings Park as a deliberately planned central reserve, bringing significant joy, and relief from urbanity, to the population of Perth and its visitors over the last 100 years. As yet we don't have significant development on our beaches, nothing like Surfers Paradise, Gold Coast and other parts of eastern Australia or for that matter the world. Our beaches are, in some ways, sacrosanct. This protection afforded to beaches has been effected in the main by good planning.

These laudable examples are swamped by an extraordinary array of examples of poor planning and abysmal foresight. We have known for many years the features that make Perth special yet we continue to see precious bushland cleared and the quality of Perth's air challenged by excessive reliance on private motor cars for transportation. How can we do things better? What do we need to consider if we want to keep the features, like Kings Park and Perth's beaches, that make Perth a special place to live?

The list entitled Perth's Ecological Baselines is a framework with which we might start to define our ecological baselines for planning.

An understanding of these features will give us a sense of our aboriginality, and an ethic of learning to live with what we have, rather than constantly demanding more from the land, air and water. Defining our place in ecological terms for planning will not diminish our capacity for healthy and wise lives.

Current decision-makers tend to believe that we can count on developing technologies to overcome, undo or fix whatever mistakes we happen to make. It places the burden and expense of dealing with our environmental problems on future generations, while we continue to cause loss or irreversible damage to our environment, reducing the options available to those future generations. Most of our environmental problems are at least partly due to our technologies, yet we remain locked into a technological-fix mentality. To better plan and prepare for our ecological future, we need to change that mental framework.

Photograph courtesy of Dieter Tracey, Water and Rivers Commission

Perth's Ecological Baselines

PERTH'S SEASONS

Hot dry summers and cool wet winters: this has implications for energy, water use and human health. Exposure of Perth people to temperature excesses and ultraviolet radiation means that we should plan for shade in summer. The occurrence of regular predictable cool temperatures in the three winter months of Perth, with sunny and windy periods means we should be able to plan for solar (or other renewable energy) heating in winter.

PERTH'S BREEZES

Perth has its characteristic breezes too. Air movements, or sometimes the lack of them, define air quality. Perth's airshed is relatively predictable; the summer shuffle of air, out with the easterlies, back in with sea breezes, reduces the clearing capacity of breezes. The airshed of the Swan Coastal Plain has potential for inversions in winter where still conditions are combined with warm air trapped beneath colder air, supporting build up of any aerial emissions at these times.

PERTH'S EVAPORATION

An annual evaporation rate that exceeds precipitation; we have to face this fact, not try everything in our power to change it. Rain comes at the time of the year when we need it least. We are placed on the edge of an extremely dry continent and climate change models have us trending even more so in that direction. Water is crucial in our planning processes. We need to maintain and enhance recent rainfall and runoff in our region. There is a vital role for our forests on and beyond the Darling Scarp here, and an understanding of the water storage capacities of our sand plain soils. We need to make sure that winter rains recharge groundwater and allow rivers to run to 'recharge' river channels, floodplains and near shore areas.

PERTH'S WETLANDS

Perth is a city of (seasonal) wetlands. In Perth there is little standing water in summer; this corresponds with high summer evaporation rates and low rainfall. Our planning tends to provide for more surface waters in summer when temperatures are high, as a way of keeping water accessible all year round. Constructed wetlands in urban areas are an obvious example. One of the results of more surface water is the exposure of people to health risks; for instance this will have significant implications for us in Perth with the prevalence of mosquito borne viruses. One step we can take is to reduce surface waters, or the period of time water spends on the surface in summer. To complicate matters we have to

be careful not to 'deep-dry' soils. Lowering of our groundwater mounds will be problematic for many reasons; one of them is the need to support the above ground vegetation (which gives shade in summer, and landscape all year).

PERTH'S FRESHWATER

We live on top of our major freshwater supply; unconfined groundwater mounds occur under the urban development on the Swan Coastal Plain in deep sandy soils. If ever there were a need to plan more effectively it is to prevent despoilation of this resource. Again, domestic, business and industrial sectors will have to play a role in minimising leakage of unwanted materials into our groundwater, and good planning must facilitate this role.

PERTH'S RIVERS

Rivers are drier and more saline as you go inland, and have a relatively low flushing capacity. Probably more than other places on Earth where rivers run stronger, we must plan to cater for low emissions from domestic, business and industrial sectors.

PERTH'S OCEANS

The ocean and the great sandy beaches provide more defining characteristics for the people of Perth. The Leeuwin current is a southern flowing current on the western edge of our continent, and it carries clear warm waters southwards, producing conditions suitable for the prolific growth of seagrasses. These seagrasses play a major role in the productivity of fisheries, provision of habitat diversity and even the production of sand itself. Increased sediment and nutrient runoff will change this by making the water column less clear, and reducing the growth potential of these aquatic plants. To protect our coastal waters and our beaches we have to keep these waters clear and clean.

PERTH'S BIODIVERSITY

High biodiversity: the living features of the Swan Coastal Plain are clearly and typically Australian, but somehow something else. The megadiverse continent spills over the Darling Range and onto the coastal plain, where a high regional diversity is produced by the mixing of cool moist adapted with drought resistant floras and faunas. The plants and animals have been isolated from the rest of the world, and from the rest of Australia. This high degree of isolation delivers (or it did once) a pest free status almost unparalleled in the world, but a susceptibility also second to none. Through our plants and animals we identify both our unique treasure and our major vulnerability.

Perth's Air: problems of photochemical smog and haze

Patrick Garnett

Perth is well known for its clean atmosphere and blue skies. To keep Perth's clear skies we need to learn more about two issues that already affect the city's air quality – photochemical smog and haze.

PHOTOCHEMICAL SMOG

The formation of photochemical smog is a phenomenon of large modern cities such as Los Angeles, Sydney and Tokyo but is also evident in Perth. Such smog is associated with reduced visibility, eye and bronchial irritation, damage to plants and animals, and deterioration of materials. Photochemical smog usually occurs on warm sunny days when the air is still. In Perth this is usually between late spring and early autumn. Photochemical smog occurs through a complicated set of chemical reactions involving nitrogen oxides and reactive organic compounds. These substances can arise from different sources, but motor vehicles are the most significant contributors. Nitrogen oxides are formed in car engines because the high temperatures in engines cause nitrogen and oxygen in the air to react forming NO, NO_2 and N_2O_4, collectively referred to as NO_x. Two of the reactions involved are:

$$N_2 + O_2 \rightarrow 2NO$$
$$2NO + O_2 \rightarrow 2NO_2$$

Nitrogen dioxide absorbs ultraviolet radiation in sunlight to form nitric oxide (NO) and oxygen atoms (O). These oxygen atoms can combine with molecular oxygen (O_2) to form ozone (O_3).

$$NO_2 + \text{ultraviolet light} \rightarrow NO + O$$
$$O_2 + O \rightarrow O_3$$

Although ozone is a poisonous reactive gas, it has an important role in the stratosphere, protecting the Earth from damaging

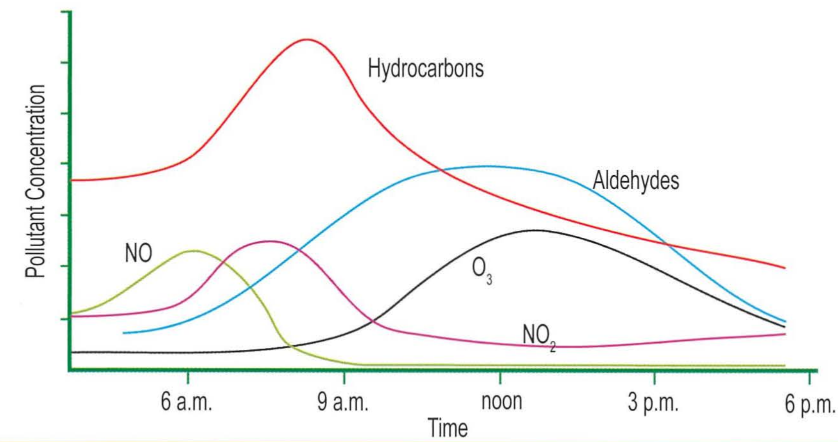


Figure 1
Changing concentrations of various gases during the formation of photochemical smog

ultraviolet rays present in sunlight. However, at ground level, it is a significant pollutant and is commonly used as an indicator of photochemical smog. Ozone molecules and oxygen atoms react with hydrocarbons emitted from vehicle exhausts, due to the incomplete burning of petrol, to produce a range of organic compounds. These include aldehydes and ketones, hydrogen peroxide, and compounds such as peroxyacetyl nitrate (PAN) and peroxybenzoyl nitrate (PBN).

Figure 1 above shows the changing concentrations of various substances during the formation of photochemical smog. The Perth Photochemical Smog Study published by Western Power and the Department of Environmental Protection in 1996 indicated that Perth has several days each year on which ozone levels exceed maximum levels set by health agencies such as the National Health and Medical Research Council. As the city continues to grow, with increasing numbers of motor vehicles, it is likely that the incidence of these smog events will increase. The formation of photochemical smog is a complicated process and identifying the best way of reducing smog formation is difficult to assess. It appears that in Perth's case, the most effective way of reducing photochemical smog is to reduce the emissions of unburned hydrocarbons from motor vehicles. Three ways of addressing this issue are:

1 Reducing motor vehicle emissions of unburned hydrocarbons by keeping cars well tuned and improving the technology used to reduce emissions.

2 Developing electrically powered motor vehicles or vehicles that utilise hydrogen as the fuel.

3 Reducing the number of motor vehicle kilometres travelled by people living in Perth. Given Perth's increasing urban sprawl and extreme dependence on the private motor vehicle as the major form of transport, this is a major challenge. It is estimated that 90% of cars driving to work in the city are one-person vehicles. To decrease the total vehicle kilometres travelled by Perth commuters may require incentives to increase inner city population densities and subsidised public transport. In addition, various taxation regimes could be developed to discourage the use of private motor vehicles when driving into the city.

HAZE

Haze is the second concern regarding Perth's atmosphere. Haze results from the presence of small airborne particles in concentrations large enough to impede vision. Particles with diameters ranging between 0.1 - 0.5 microns (1 - 5 ten millionths of a metre) are mainly responsible for the scattering of visible light that results in haze.

The Perth Haze Study was published in 1996 by the CSIRO Division of Atmospheric Research and the Department of Environmental Protection. That study found that haze in Perth occurs mainly in the winter months. Using criteria such as visibility (less than 20 km is regarded as unacceptable) or PM10 levels, concentration in $\mu g/m^3$ of particles up to 10 microns diameter, (with a target 24-hour average maximum of 50 $\mu g/m^3$), Perth has several episodes of unacceptable haze each year. The Perth Haze Study reported that:

1 Smoke was the most significant contributor to winter haze levels. Smoke occurs from biomass burning such as the use of domestic wood heaters, burning off and bush fires.

2 Motor vehicles are the second largest contributor to winter haze. About two thirds of these motor vehicle emissions occur from diesel powered vehicles.

High haze levels are aesthetically unattractive, but studies have also established associations between airborne particle concentrations and

Haze over Perth

Photograph courtesy of The West Australian health problems including respiratory ailments, heart related deaths and lung cancer. Although Perth haze levels are lower than those cities in which these studies have been undertaken, there is the potential for haze levels to increase and for this to impact negatively on the health of Perth inhabitants.

To reduce haze levels in Perth a range of measures has been introduced in the Perth Air Quality Improvement Plan published in 2000. These measures will need to be supplemented in future years as Perth's population grows.

Some initiatives that would reduce the impact of haze in Perth skies are:

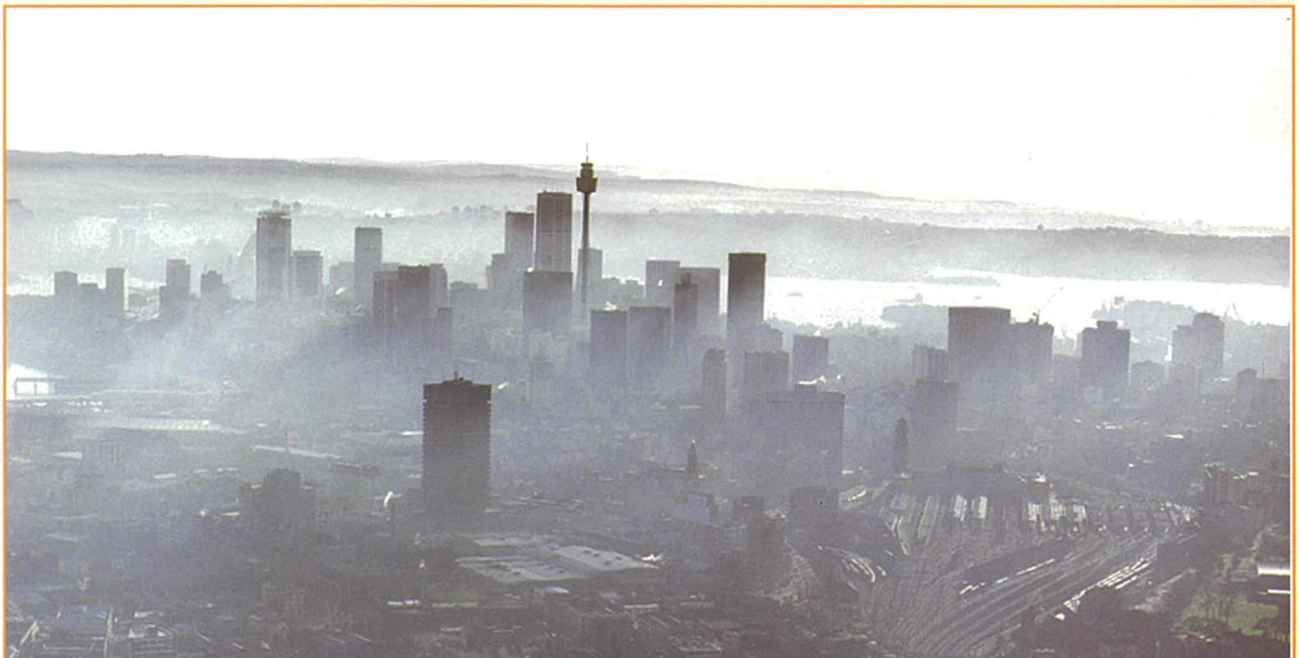
1 Householders operating wood heaters neead to use these heaters responsibly, burning only dry, unpainted wood. It is preferable to use gas heaters for domestic heating and, at some point in the future, it is likely that the use of domestic wood heaters will need to be banned.

2 Prohibiting backyard burning in the metropolitan area, as has already been implemented in Sydney.

3 Reducing the incidence of smoke events produced by burning off in rural areas. Already CALM avoids prescribed burning if prevailing winds are likely to take the smoke to Perth.

4 Reducing smoke emissions from vehicles by keeping engines tuned, introducing periodic vehicle emissions testing, and replacing diesel powered vehicles wherever possible.

While the quality of Perth's atmosphere is high by international standards, the city's increasing population is beginning to impact negatively on its air quality. By addressing these concerns now it should be possible to maintain Perth's reputation for an outstanding healthy natural environment.



Smog over Sydney

Photograph courtesy of Photolibrary.com

The Greenhouse Effect & Global Warming

Patrick Garnett

The Earth receives energy from incoming solar radiation (sunlight) and itself radiates energy (infrared radiation) back into space. Some of the energy the Earth radiates back into space as infrared radiation is trapped in the atmosphere. As a result, the Earth is warmer than it would be if it had no atmosphere. The average temperature of the Earth's atmosphere is about 15 °C. If the Earth had no atmosphere, the average temperature would be about -18 °C. The Earth therefore has a natural greenhouse effect (see Figure 1).

The Earth's natural greenhouse effect is due mainly to the presence of carbon dioxide (CO_2) and water (H_2O) molecules in the atmosphere. These molecules are responsible for absorbing infrared radiation emitted by the Earth.

Today, there is considerable discussion about the enhancement of the Earth's greenhouse

Gas	Major sources of greenhouse gases due to human activity
Carbon dioxide (CO_2)	Combustion of fossil fuels; deforestation
Methane (CH_4)	Ruminant animals e.g. cows and sheep; rice paddy fields; extraction of natural gas; landfill garbage dumps
Nitrous oxide (N_2O)	Biomass burning; fertiliser use
Ozone (O_3)	Product of photochemical smog caused by motor vehicles
CFCs	Formerly used as aerosol propellants; refrigerants; solvents

Table 1
Major sources of greenhouse gases due to human activity

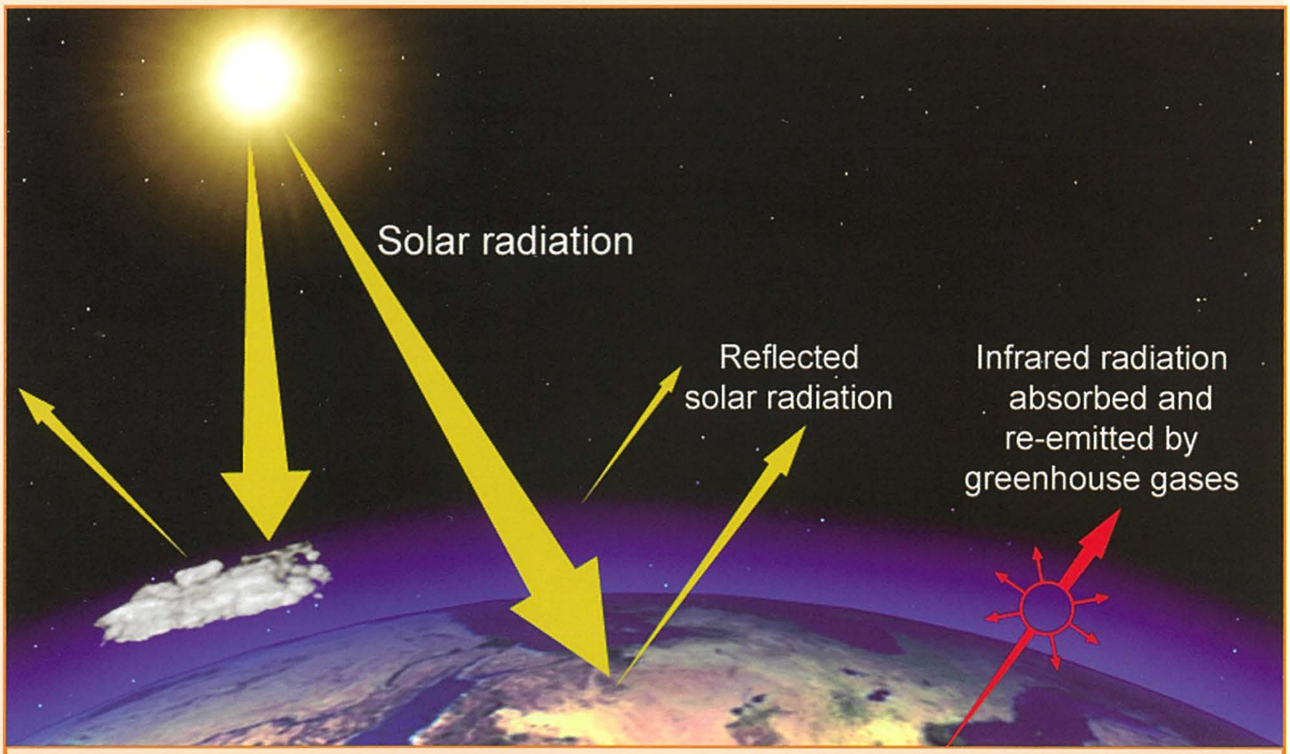


Figure 1
The Earth has a natural greenhouse effect

effect due to changing concentrations of some of the gases in the Earth's atmosphere. The gases that contribute most to this enhanced greenhouse effect are carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs). Although these gases are minor constituents in the Earth's atmosphere they are relatively more affected by human activities than nitrogen (N_2) and oxygen (O_2) which are the most abundant gases in the atmosphere.

The human activities thought to have the greatest effect on the concentrations of the minor constituents in the Earth's atmosphere are set out in Table 1.

Table 2 shows the changes in concentration of three of the major greenhouse gases from pre-industrial times to the present and projected to the year 2100, assuming continued commitment to the use of fossil fuels.

It is clear that human activities are changing the composition of the atmosphere. Changes to the major atmospheric gases, nitrogen and oxygen, are insignificant. However the relative changes in the concentrations of the minor atmospheric gases are quite marked. For example, carbon dioxide levels have increased by 30% over the last 150 years and are projected to double again by the end of the 21st century.

The effect of these changes in concentration of the minor atmospheric gases on climate is difficult to establish because of the large natural variations in the Earth's climatic systems. However, the Inter-governmental Panel on Climate Change (IPCC) recently concluded that during the last century the Earth's temperature increased by 0.6°C, sea levels increased by 10-20 cm, cloud cover over land increased by 2%, and snow cover has decreased by 10% since the 1960s. The IPCC is confident that these changes are the result of human activities.

Gas	Pre-industrial level	Present level	Predicted 2100 level
CO_2 (ppm)	280	365	540-970
CH_4 (ppb)	700	1760	1570-3730
N_2O (ppb)	270	315	350-460

Table 2
Predicted changes in greenhouse gas levels.

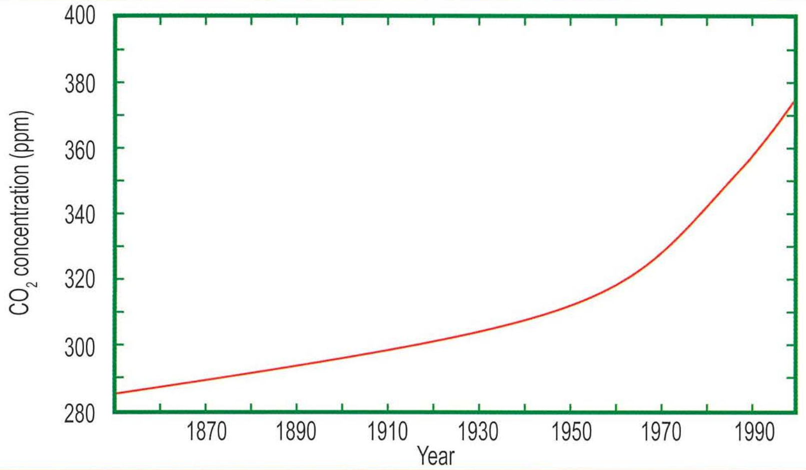


Figure 2
Changes in carbon dioxide levels in the atmosphere over the last 150 years

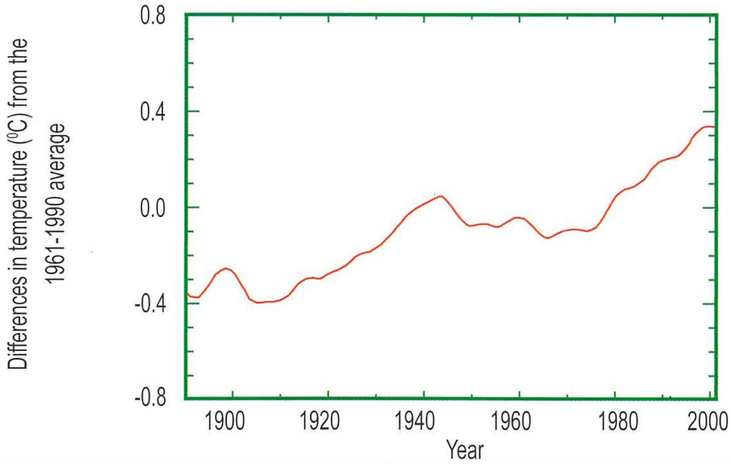


Figure 3
The average global temperature is estimated to have increased by 0.6 °C over the last century.

Adapted from http://ipcc-ddc.cru.uea.ac.uk/; Climate Change 2001: The Scientific Basis. Summary for Policy Makers

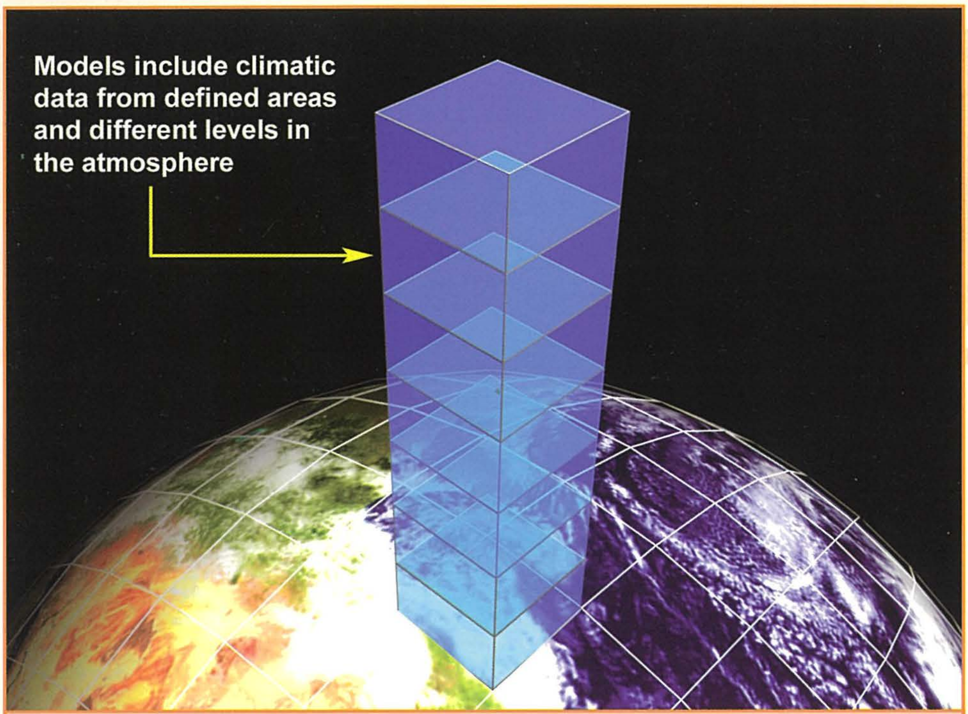


Figure 4
General Circulation Models attempt to predict the effect of changing atmospheric concentrations on Earth's climate.

A great deal of work is currently being undertaken in several countries to predict the possible changes to the Earth's climate resulting from its changing atmospheric composition. Scientists are using computer models called General Circulation Models (GCMs) which consist of extremely complicated mathematical equations used to predict winds, temperatures, pressures, cloud cover and precipitation as changes in atmospheric composition take place.

These models are both complex and crude. The models contain huge amounts of information, but are crude in that one data point may represent a 500 km square grid on the Earth's surface. The different models also include several vertical levels in the atmosphere. There are considerable difficulties in trying to deal with the complexities of atmospheric circulation patterns, the interaction of ocean and atmospheric dynamics and the feedback processes associated with clouds, the biosphere and the Earth's surface snow and ice cover. The models require a super computer to provide the computing power needed for their application.

The postulated consequences of changes in the Earth's atmosphere vary from model to model and there is considerable debate on the extent of the changes that are likely to take place. As well as the difficulties of modelling climate based on different atmospheric compositions, different greenhouse gas emission scenarios can have a significant effect on climate predictions. Given the range of models and possible emission scenarios there is considerable variation in the predicted climate changes that may take place over this century. Possible changes include:

1 Temperature increases of the order of 1.4 - 5.8 °C

2 Increased but uneven rainfall (10%)

3 Rising sea levels (10-90 cm)

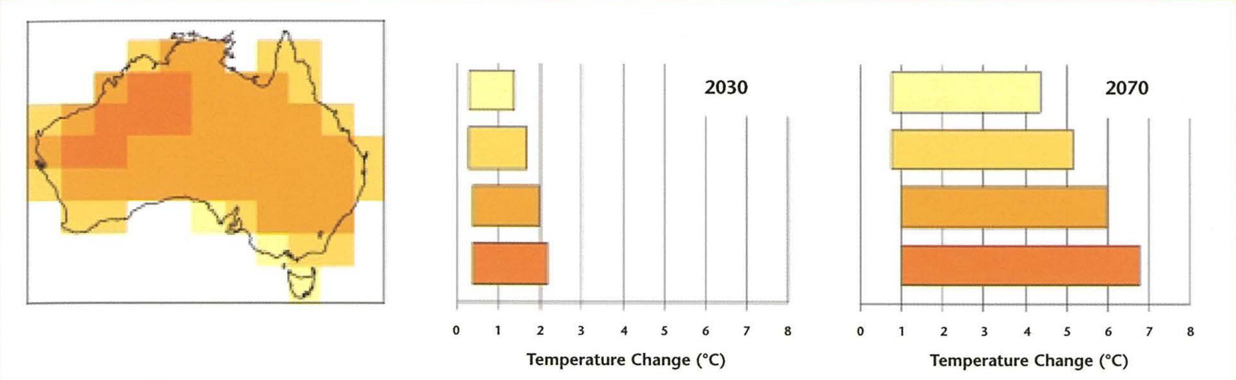
4 Changes in ocean circulation patterns

5 Poleward shift of climatic zones

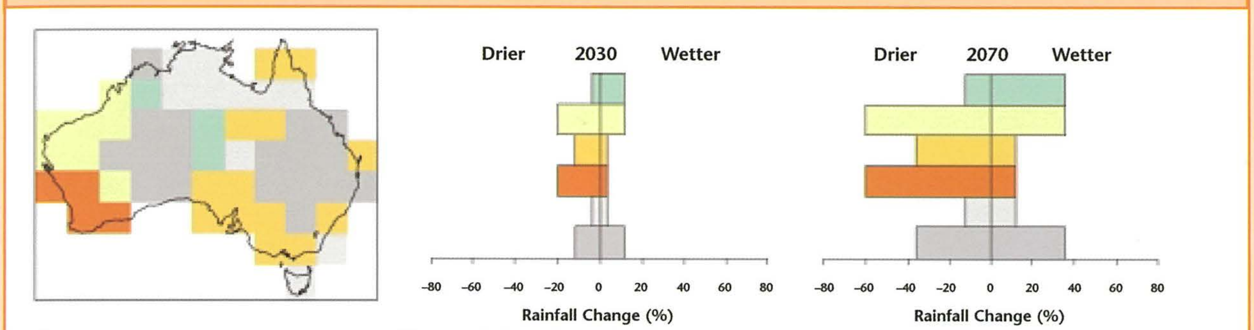
6 Increased frequency of extreme weather events

7 Threat to some ecosystems and many plants and animals due to the rapidity of climate change

The uncertainty of the predictions arising from "greenhouse science" makes policy setting a dilemma for decision makers. The two extremes in position can be summarised as follows:



a) Temperature
Projected average annual warming (^{0}C) for 2030 and 2070 compared to 1990



b) Rainfall
Projected average annual rainfall changes for 2030 and 2070 compared to 1990

Figure 5
Possible climate changes in Australia resulting from the enhanced greenhouse effect: a) temperature, b) rainfall.

Images courtesy of CSIRO Atmospheric Research

1 Policy makers must wait for greenhouse science to get better. It is premature to make policies based on limited data especially as the economic consequences may be severe.

2 Uncertainty should not be used as an excuse for inaction as the longer action is delayed the greater the extent to which the Earth will be committed to irreversible global warming.

Several international meetings have discussed the greenhouse effect and global warming with a view to stabilising greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous interference with the climatic system. The Kyoto Protocol, signed in 1998, set greenhouse emission targets that aimed to reduce emissions to 5% below 1990 levels by 2008-2012. Already some countries, including Australia and the U.S.A., have raised concerns about the potential impact of these targets on economic growth and refused to accept the convention.

This issue is sure to generate continuing debate over the next few decades. It is likely to be several years before we have sufficient evidence to confidently and accurately predict the climatic consequences of changing atmospheric composition. However, the message is perfectly clear. As part of the global village that all humans inhabit it will be increasingly important to undertake a range of measures aimed at reducing greenhouse gas emissions. These will include increased energy efficiencies, much greater development and use of renewable energies, preferred use of natural gas over oil and coal, and improved land management practices.

Ozone Depletion in the Stratosphere

Patrick Garnett

The stratosphere is a region of the Earth's atmosphere between about 15 and 50 kilometres above the Earth's surface. It contains ozone, O_3, in concentrations about 10 parts per million (ppm). This triatomic (three atom) form of oxygen is very reactive at ground level where it reacts with many other substances. In the stratosphere it has a much longer lifetime due to the thinner atmosphere at these altitudes (see Figure 1).

Ozone has an important role in preventing harmful ultraviolet light in sunlight from reaching the Earth's surface. Although the 'ozone layer' is important to our survival, it is quite fragile. If you were to compress all the ozone in the stratosphere to sea level, it would only occupy a layer about 3 mm thick.

Within the stratosphere, ozone is produced and broken down by a series of reactions that can be represented as follows:

Production

O_2 + ultraviolet light $\rightarrow$ 2O

$O_2 + O \rightarrow O_3$

Decomposition

O_3 + ultraviolet light $\rightarrow O_2 + O$

$O + O \rightarrow O_2$

Normally these production and decomposition processes maintain ozone levels at a more or less steady state concentration. However, some chemical species can catalyse the rate of decomposition of ozone and bring about a reduction in ozone concentration. Examples of chemical species that can catalyse the decomposition reaction are nitric oxide (NO), chlorine (Cl) atoms and hydroxy (OH) radicals.

As early as 1974, some scientists warned of the potential threat which chlorofluorocarbons (CFCs) posed to the ozone layer. Then, in the

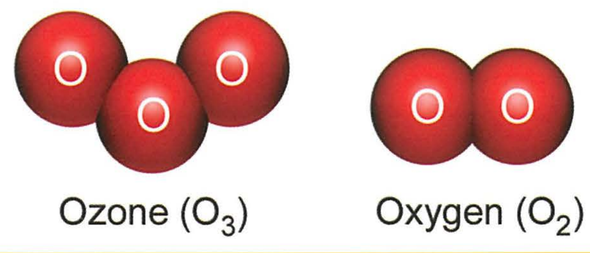


Figure 1

An ozone (O_3) molecule contains three oxygen atoms whereas an oxygen (O_2) molecule contains two oxygen atoms

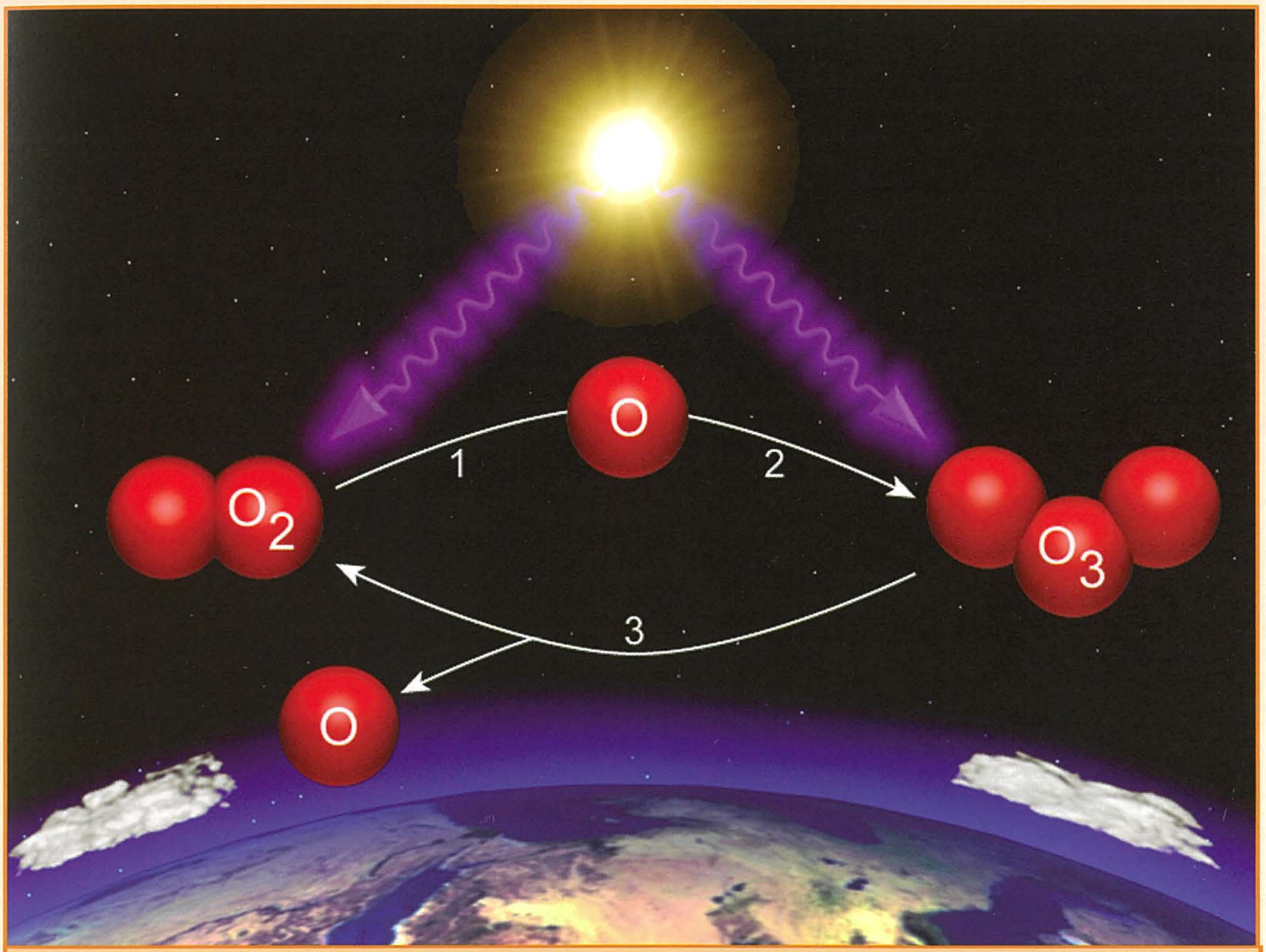


Figure 2
The production and decomposition of ozone in the stratosphere

mid-1980s, large decreases in stratospheric ozone were observed over the Antarctic. These large decreases were described as 'holes' in the ozone layer. The holes are most apparent over the Antarctic in early spring and disappear gradually in late spring and summer as ozone-rich air flows in from lower latitudes.

There was considerable scientific debate regarding the cause of this decline in stratospheric ozone concentrations. Increased NO, the presence of CFCs and changing atmospheric circulation patterns were all mentioned as possible causes.

A crucial experiment conducted by the National Aeronautics and Space Administration (NASA) was planned to investigate the phenomenon. The Airborne Antarctic Ozone Experiment, conducted in spring 1987, provided vital evidence that implicated CFCs as being responsible for the decline in ozone concentrations. This experiment involved about 150 scientists, ground-based and aeroplane-based laboratories. The experiment involved analysing stratospheric chemical species as a function of latitude. At high latitudes, ozone concentrations were almost a mirror image of ClO concentrations. This was powerful evidence that chlorine present in the stratosphere was the major cause of ozone depletion. This chlorine is produced from the photochemical decomposition of CFCs as they diffuse to higher altitudes in the atmosphere.

The reason that ozone levels fall so drastically over the Antarctic during spring seems to be the peculiar meteorological conditions that exist at this time of the year. Air above the Antarctic is stagnant during winter and early spring. This very cold air produces stratospheric clouds containing ice particles that play a critical part in the catalytic decomposition of the ozone.
There has been an estimated loss of about 3-4% of ozone in the stratosphere worldwide over the past 20 years, and much greater losses in spring over high southern latitudes. The reduction in ozone concentrations results in higher levels of ultraviolet light reaching the

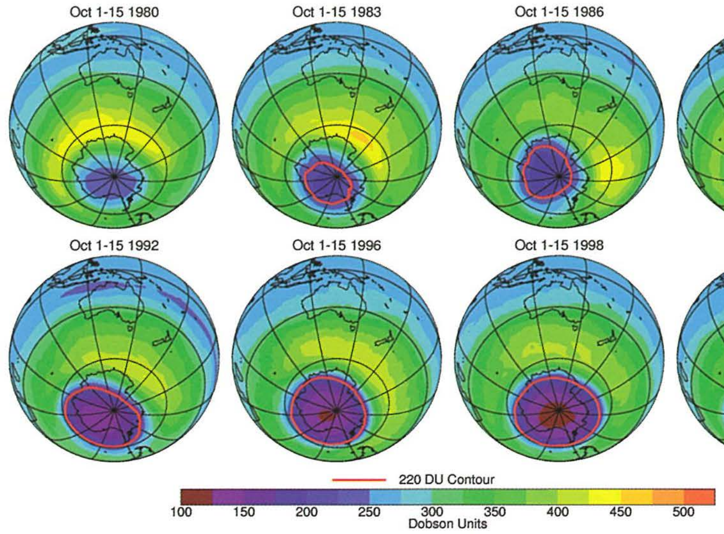


Figure 3
'Holes' in the ozone layer above the Antarctic resulting from ozone depletion.

Images courtesy of Paul Krummel, CSIRO Atmospheric Research; data from NASA/GSFC TOMS Ozone Processing Team

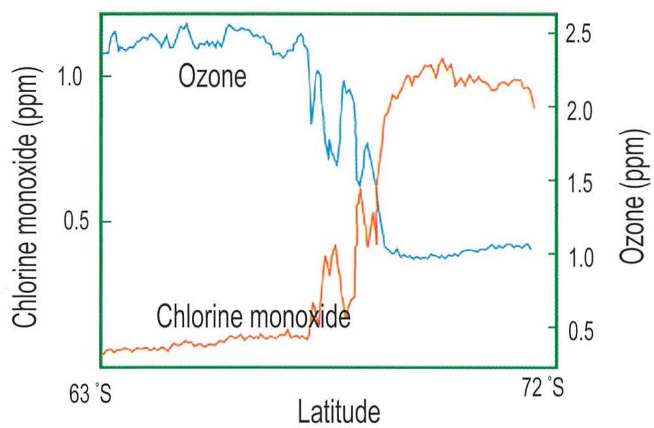


Figure 4

Mirror images of O_3 and ClO concentrations above the Antarctic suggested CFCs were responsible for ozone depletion.

Adapted from http://see.gsfc.nasa.gov/edu/SEES/strat/class/Chap_11/index.htm

Earth's surface. This can lead to increases in sunburn and skin cancer, damage to plants and possibly damage to sensitive ecosystems such as those found in the Antarctic. For example, it is estimated that a 1% decrease in stratospheric ozone concentration would lead to a 4-6% increase in skin cancer rates in humans.

As a result of the NASA experiment, governments around the world have moved quickly to phase out the use of CFCs. These included uses as aerosol propellants, foaming agents in plastic foams, refrigerants and solvents. A series of international agreements starting with the 1987 Montreal Protocol brought forward the phasing out of most CFCs in industrialised countries to 1995. Despite this phasing out it is predicted that it will take the best part of a century for atmospheric chlorine levels to decrease to their 1980 levels. This is because of the long lifetime of CFCs already present in the atmosphere.

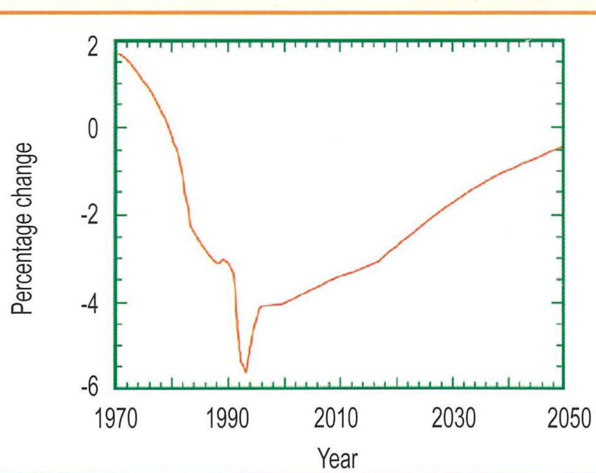


Figure 5

Predicted ozone concentrations in the stratosphere over the period 1970-2050

Adapted from UK Stratospheric Review Group (Eds) "Stratospheric Ozone 1988", HMSO, London

Keeping Birds in the City: birdlife in Kings Park

Harry Recher

Kings Park is an urban icon. Without Kings Park, Perth would not be Perth and the sense of living in a clean, green city would vanish. Since 1986, Professor Harry Recher of the School of Natural Sciences at Edith Cowan University has been studying the birds of Kings Park. This work began when Dr. Recher was on a sabbatical at Curtin University from the Australian Museum in Sydney where he worked at that time. The study of Kings Park's birds has two objectives. The first is to document the changes in the animals of urban bushland that occur over time and the second is to find ways to conserve as much of the Park's wildlife as is possible in a bushland remnant now isolated in the middle of a large and growing city.

Despite 170 years of disturbance and change, Kings Park's open space and bushland are highly valued by West Australians. Both foster a feeling of naturalness which users of the park experience. Not least, the sound, movement and colour of birds are part of Kings Park and do much to reinforce the sense of nature that one encounters when walking, jogging or riding through this urban green space. Ensuring that birds remain part of Kings Park is therefore as important as retaining its wildflowers and open spaces.

Two hundred and sixtyseven hectares of the park remain as native vegetation and the park has a rich flora and fauna. More than 80 species have been recorded within the park's boundaries. Despite the large amount of native vegetation, Kings Park is not pristine and has

changed in many ways since the settlement of Perth by Europeans in 1829. These changes to the park, as well as changes to the urban matrix in which the park is found, have produced a dynamic and changing avifauna.
Counts of birds are available for a transect from the Saw Avenue entrance through Kings Park to the University of Western Australia on Park Road from 1928 to 2002. In that time, 58 species of terrestrial birds have been recorded along the transect. Of these, 20% increased in abundance and 40% decreased with 10 species proceeding to extinction within the park. Since 1928, Kings Park and the urban landscape of Perth has been increasingly dominated by large nectar-feeding (honeyeaters) and seed-eating (parrots) birds. Small insect-eating birds (thornbills and robins) have declined in abundance or become locally extinct. The decline of most species can be attributed to the park's increasing isolation as Perth has grown, as well as to changes to the park's vegetation, changed fire regimes,

nest predation, and weeds. Changes to forest and woodland habitats outside the Perth region coupled with the loss of other urban bushland remnants are also factors bringing about change in birdlife.
Despite these changes, the birds of Kings Park are as rich and abundant as they were in 1928 when censuses commenced. The avifauna is just different. Ensuring that there are birds in an urban landscape is not difficult and may not require any special management. All cities, even the most densely populated, have birds, often in large numbers. However, most city birds are urban commensals, species that associate with humans and find an abundance of food and nesting sites wherever people aggregate. These birds, the pigeons, sparrows and starlings of the inner city, require little encouragement. What is difficult is creating or maintaining an environment within the urban landscape which attracts and retains species which are not human commensals and for which the urban environment is alien and inhospitable.
For example, if small birds and insectivores are desired, then changes need to be made not only to the management of Kings Park, but to the way vegetation in the urban matrix is managed. Foremost among the changes needed is the progressive replacement of exotic trees and shrubs along roads and in parks and gardens with native species. Some of this is already happening and is necessary to foster an abundant arthropod fauna for insectivores to feed upon. Whether such changes are essential or even desirable depends on the reasons why people want birds about them in the city and suburbs. It may be that it is only important to have birds and not important as to which species are represented.
Studies of urban ecology are among the many areas of education and career development available at Edith Cowan University. Understanding how urban ecology works is important for careers in planning, environmental design and management, local government and education, among many others.

The Swan River: our natural heritage under siege

Paul Lavery

The Swan - Canning Estuary runs through the centre of Perth providing a magnificent view and exceptional recreational opportunities in the middle of a large urban setting. Over a million people living in Perth enjoy the benefits of these rivers and their estuary. The system is used for sailing, rowing and other water sports, supports both recreational and commercial fishing and is a valued backdrop for picnics, cycling and rowing. However human activities since European settlement, about 170 years ago, have placed pressures on the estuary, and today there is growing concern over the occurrence of algal blooms and fish kills and increasing calls to "Save Our Swan".

The estuary begins hundreds of kilometres inland in the Avon river catchment and winds its way through the Avon Valley before joining the Helena River and becoming the Swan River. The catchment of these rivers is about the same size as Tasmania and is largely agricultural land. The Canning River merges with the Swan River in Applecross, and they both then discharge to the Indian Ocean at Fremantle.

Up until early last century, sewage was discharged to the estuary. That practice

Photograph courtesy of The West Australian has long since ceased, but land uses in the catchment now pose a serious threat to the rivers and their estuary. Land clearing and the use of fertilisers in the catchment led to an increase in nutrient loads in the river. These nutrients stimulate the growth of algae in the water column, and under certain conditions, this can lead to excessive algal growth, anoxia (the depletion of oxygen) and the death of fish and other fauna.

WHAT ARE NUTRIENTS AND WHY ARE THEY A CONCERN?

Nutrients are elements essential for the growth and maintenance of organisms. In that sense, all nutrients are essential to maintaining healthy ecosystems. In excess, nutrients can lead to problems associated with too much growth. In the Swan River, as with many other estuaries, nitrogen and phosphorus are the nutrients of most concern. These nutrients accumulate on the surface of the land through human activities such as applying fertilisers to farmland and gardens and as animal manure and plant material. Some of this nutrient store is washed off the land during rainfall events and drains into the river. Other parts of the nutrient store leach down into the groundwater and drain more slowly to the river. Once in the river, they act much as fertilisers do on a lawn, stimulating plant and algal growth.

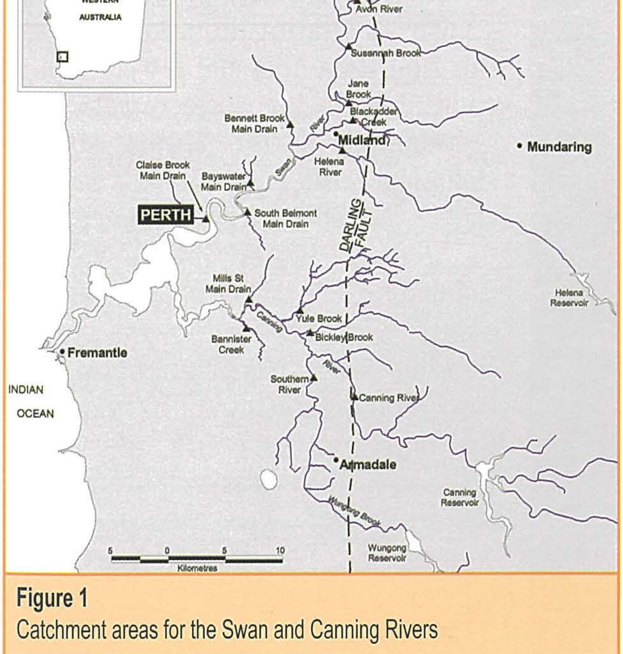
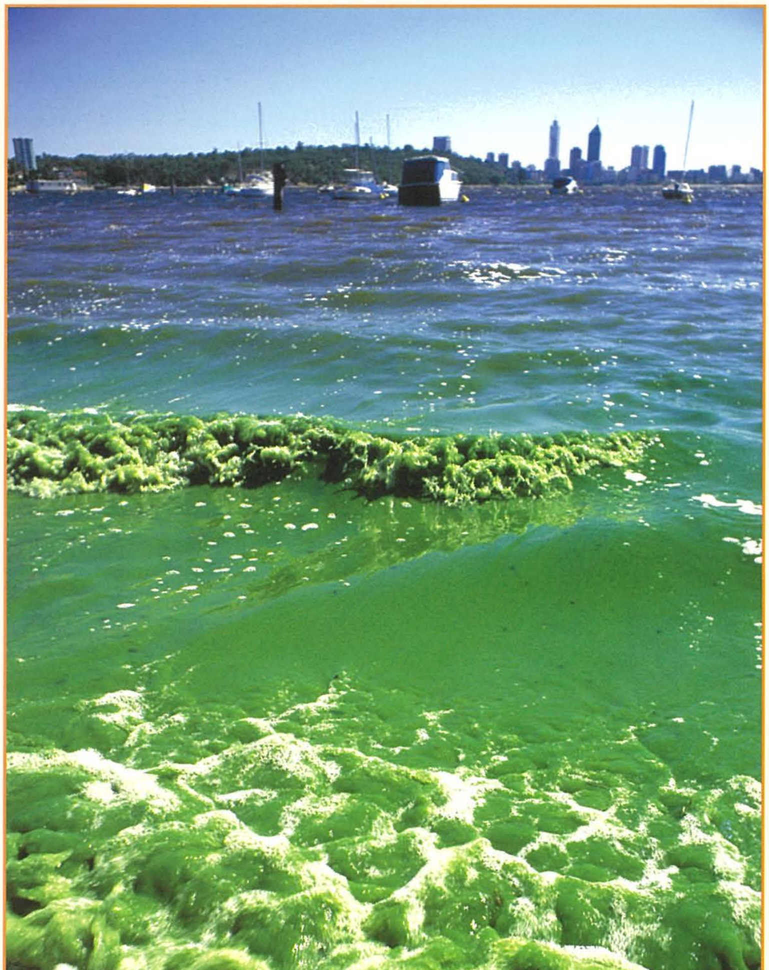


Figure 1
Catchment areas for the Swan and Canning Rivers

Figure courtesy of the Water and Rivers Commission

Phytoplankton are microscopic algae that provide a valuable food source for many estuarine fauna. They are an essential part of any estuarine food web. Under healthy conditions the concentration of phytoplankton is relatively low and consists of a diverse range of species. However, when excessive amounts of nutrients enter the system, some forms of phytoplankton may proliferate to concentrations well above normal, an event referred to as an algal bloom.

Algal blooms are a concern for several reasons, but toxicity and anoxia are the two major concerns. If the bloom consists of toxic algae there can be direct health implications. A major bloom occurred in the Swan River in 2000 comprising the toxic blue-green alga *Microcystis aeruginosa*. This species can produce a toxin (*microcystin*) that is potentially fatal to mammals. At concentrations of more than 20 000 algal cells per mL this species is considered a health concern. During the summer of 2000, concentrations as high as 130 million cells per mL were recorded in some parts of the Swan River. At other times, the river has experienced blooms of dinoflagellates (known as red tides because they give the water a brick-red colour), which can also be toxic, affecting the nervous system or liver function. Non toxic blooms can also be a concern because of their consumption of oxygen. During the day phytoplankton photosynthesise, producing oxygen. At night they respire, consuming oxygen and possibly driving concentrations unacceptably low. However, it is when a bloom 'collapses' that anoxia can be most significant. When an algal bloom finally runs out of nutrients or conditions become unfavourable, it will die or collapse. At this point, the dead algal cells are consumed by bacteria and, in the process, oxygen is consumed. At these times, it is possible to remove almost all of the oxygen from the water column, with catastrophic effects for other organisms living in the estuary.



Photograph courtesy of Dennis Sarson/Lochman Transparencies

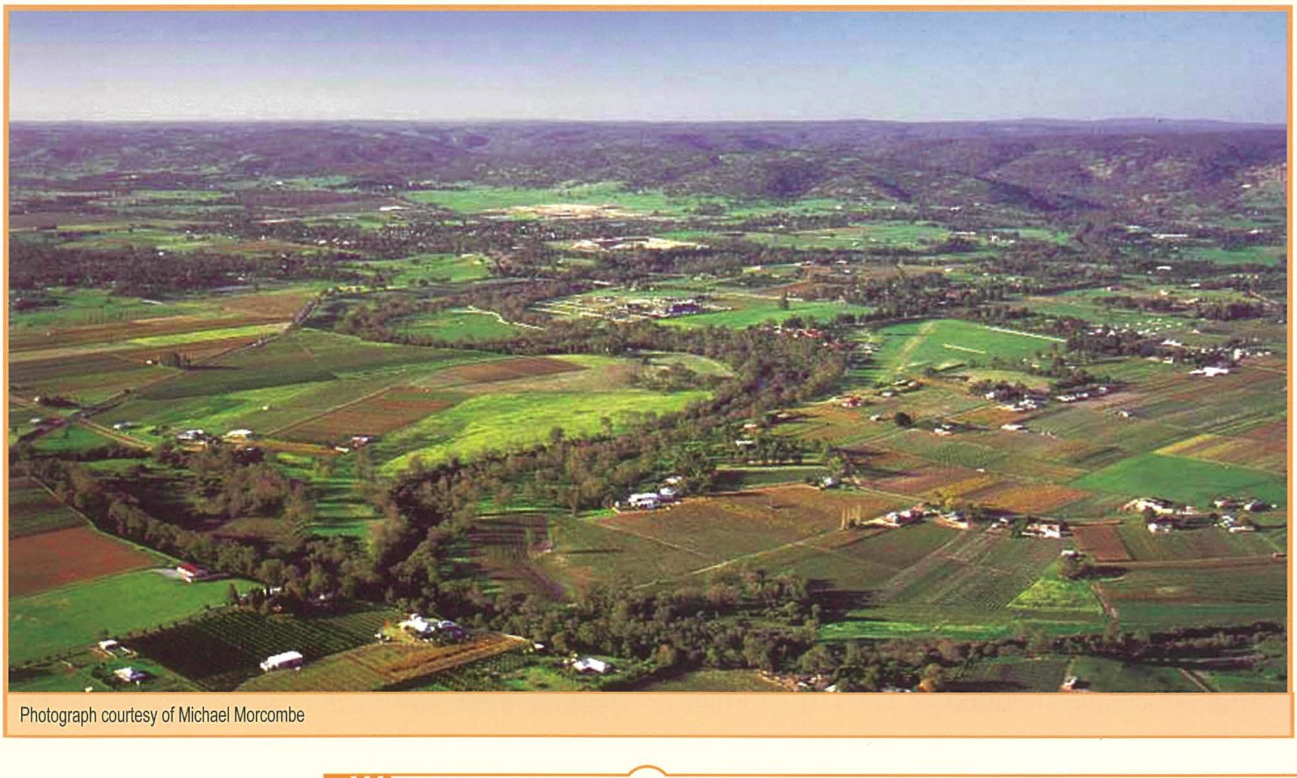
RECIPE FOR CATASTROPHE

Algal blooms do not occur all the time, and even when they do occur they do not always lead to catastrophe. The most significant harm occurs when the right combination of river flow, salinity, temperature and sunlight occur, and early summer rains have the capacity to lead to the most severe blooms. At these times, the estuary is usually full of marine water, which intrudes from the ocean at Fremantle. If there is sufficient rainfall, freshwater can enter from the catchment carrying nutrients with it. Because freshwater is less dense than salty marine water, the incoming water tends to sit on top of the saltwater, forming a freshwater lens, a condition known as stratification. *Microcystis* can flourish under the lower salinity conditions in the surface water and grow rapidly on the nutrient supply. Meanwhile, the layer of fresh surface water prevents oxygen penetrating to the deeper water, and the shading caused by the algal bloom can kill plants and other algae in the bottom waters. Under these conditions there is a gradual depletion of oxygen from the bottom waters and, ultimately, this can lead to anoxia. This process is significantly enhanced once the *Microcystis* bloom collapses and falls into the bottom waters, where it decomposes. This sort of scenario does not always involve *Microcystis*. Other algae that are less dependent on low salinity conditions can also bloom, and, under stratified conditions, this can lead to bottom water anoxia.

WHAT HOPE FOR OUR RIVER?

The only sustainable, long-term solution to the problem is to reduce the input of nutrients to the system through catchment management. This means regulating the discharge of pollution from industry as well as the run-off that comes from agricultural and urban catchments. While it is relatively easy to regulate industries, it can be more difficult to control diffuse sources of nutrients from catchments, such as fertiliser application to our gardens and farms. Managing these diffuse sources often requires a combination of regulations, education and cooperation from the whole community.

Catchment management is a complex and often slow process. In the shorter-term it is possible to undertake other forms of management that are designed to maintain the quality of the estuary at a reasonable level until the longer-term measures take effect. In the Swan River a major scientific study was undertaken in 1996-99 to identify the causes of the blooms and possible short-term measures that could be used to control them. The Swan River Cleanup programme involved managers and scientists from a wide range of government agencies and universities, including Edith Cowan University. Research at ECU has examined how nutrients are released from the sediments and how algae can influence the types and amounts of nutrients released. Emerging from this and other research have been several short-term management approaches. These have included pumping deeper saltwater onto the surface algal bloom to kill them and to help break down stratification, and pumping oxygen into the water column. The injection of oxygen helps to replace oxygen lost during algal decomposition and also helps to remove nitrogen from the system and to lock phosphorus into the sediments, where it is not available to stimulate algal growth. These and other short-term solutions will not save our river. Today's management of the river involves a range of short-term and long-term strategies being applied at the same time. Ultimately, however, saving the Swan depends on us all changing the way we behave so that our catchments leak less nutrients to our streams and groundwater.



Photograph courtesy of Michael Morcombe

Controlling Nuisance Midges

Mark Lund

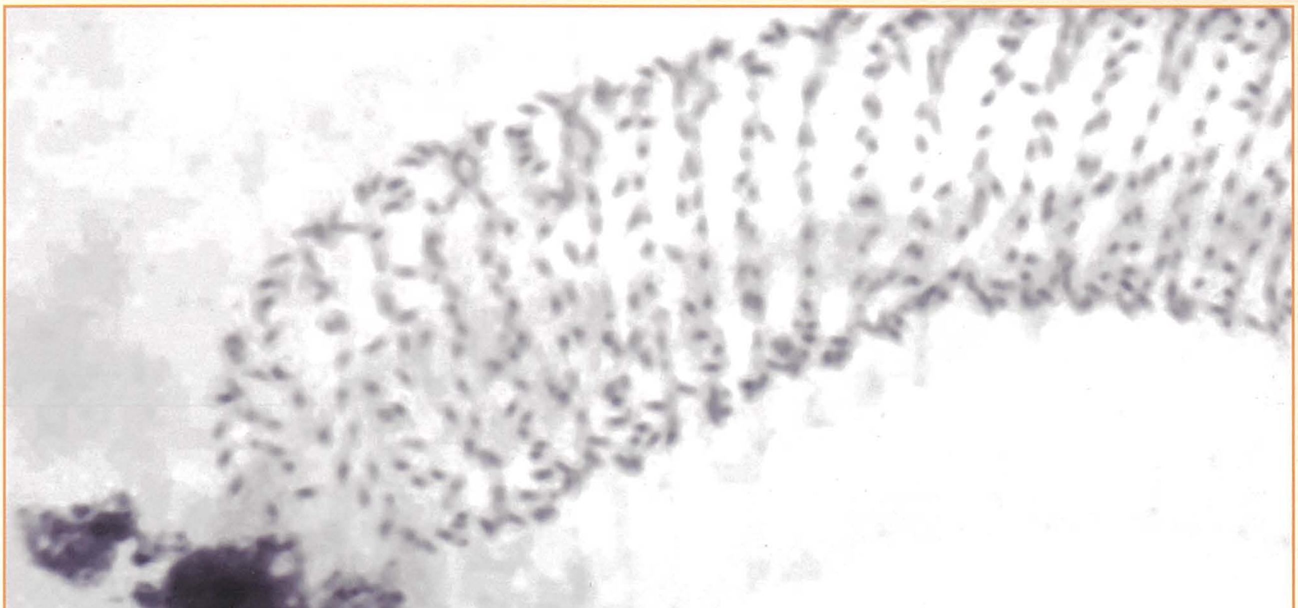
No one likes wetlands or lakes with poor water quality, but several insect species do. In particular some species of the *Chironomidae* (non-biting midges) thrive under these conditions. Non-biting midges are similar in size and shape to mosquitoes, but do not bite. Adult midges lay eggs in wetlands, the eggs hatch to produce larvae (commonly called bloodworms) that live in or near the lake bed. They then form pupae which swim to the water surface and out emerges the adult midge. The main purpose of the adult is to reproduce, which many do forming large spiral masses over the water surface. Adults generally do not live beyond a couple of weeks.

This all sounds very pleasant, but when several million adults emerge from a lake on a summer night and head towards the nearest lights you can have a problem. As most adults emerge during spring and summer the lights they are heading for are around your barbecue. Residents living near to wetlands can have their outdoor activities severely restricted during summer when huge clouds of midges descend on their homes. Despite the fact they are non-biting, sheer numbers make it hard to keep from swallowing them or getting them in your eyes. Nuisance plagues of midges have been annoying residents surrounding Lake Joondalup for the last few years. The ultimate cause of the problem is human development around the lake, which has resulted in deteriorating water quality within the lake. The only short-term solution to the problem is to drop small pellets of a pesticide to the lake bed and kill the larvae before they emerge.

As an Environmental Manager this is a type of problem that you could easily face, on one hand you have a valuable ecosystem that has deteriorated and on the other residents who are suffering a severe decline in their quality of life. On the environmental side, you obviously would like to improve water quality within the lake, which would ultimately eliminate the midge problem, but this may take from 5 to 50 years to be effective. On the human side, you have the detrimental impact the midges have on quality of life, land prices and community. You need a short-term solution, but the only one available is a pesticide, which is not good for the lake.

This dilemma faced Dr Mark Lund of the Centre for Ecosystem Management at ECU in 1999 when he was asked to conduct research into the midge problem at Lake Joondalup. A survey of the lake revealed that midge larvae were concentrated into two 'hotspot' areas. These could be treated with pesticide, while leaving some of the lake unaffected. The pesticide does affect other organisms besides midges and treating only some of the lake provided a refuge for these species while reducing the problems for residents. This new approach is an improvement on control methods for midges in Perth, where an entire lake is treated with the pesticide. However, the use of pesticide is only a short-term solution and Dr Lund has been actively involved in both a public education campaign and in developing a longer term rehabilitation plan for Lake Joondalup.

Good environmental management involves people and the environment and tries to find a 'win win' solution to an environmental problem. At Lake Joondalup, improvement of the lake's water quality will eventually help reduce the midge problem, and in the process will benefit a wide range of environmental objectives. The residents, through their actions will benefit from reduced midge plagues and a more natural ecosystem on their doorsteps.



Water: a precious resource

Harry Recher

Australia is a dry continent and supplying fresh water to farms, factories and homes is one of the greatest environmental challenges we face. In recent years, Perth, Melbourne and Sydney, along with many regional centres, had water restrictions including bans on sprinklers, washing cars and hosing off driveways. The restrictions are the result of increased demands for water as Australia's population has grown, our greater wealth and more luxuriant life styles compared with our grandparents, and drought. For Western Australians, drought has become a fact of life. Since the 1970s, annual rainfall in the Southwest has declined by 20 percent and this has affected the amount of water entering reservoirs and rivers. Perth has compensated by using groundwater to supplement the water available from catchments, but this is not without its problems. Lowering the water table by extracting groundwater can not only affect wetlands and native vegetation, it can lead to the intrusion of unwanted substances or contaminated water as has happened in many places in North America. Learning how to manage the extraction of groundwater and the wetlands for which Perth is famous are major interests of staff and students at Edith Cowan University. Their goal is to find ways to provide water for Perth without compromising Perth's natural environments. Managing our wetlands and waterways is also important outside the metropolitan area. River restoration is an essential part of caring for the land. In the same way, utilising and managing water filled voids created by mining adds a dimension to water management that may not receive much publicity, but is necessary both to prevent pollution and change what might be seen as a problem into a valuable resource. Water, wetlands and rivers feature among the work and interests of staff and students in Environmental Management at Edith Cowan University. Students studying environmental management at ECU therefore receive hands on experience with protecting and restoring our most precious resource.

Groundwater Dependent Ecosystems

Ray Froend and Sandra Zencich

In Perth, the future of groundwater resources is being assessed due to increasing use (pumping) of this resource to supply the people of Perth with water. Up to 60% of the water used in Perth comes from groundwater. The role groundwater plays in supporting our environment is also being assessed. Groundwater has been shown to be important to many plants and animals in ecosystems across Western Australia. These are known as groundwater-dependent ecosystems and can be defined as a complex community of organisms where groundwater is a key resource required for consumptive use, biophysical processes or as a habitat. Groundwater pumping for human use can lead to a decline in the level of the groundwater table affecting components of the ecosystem that rely on this water source. To ensure the continued health of groundwater-dependent ecosystems, their water requirements need to be identified and formally recognised by environmental management agencies so that sufficient water can be allocated to meet those requirements. However, the groundwater requirements (meaning how much groundwater is needed and at what times of the year) of these different ecosystems are poorly understood. If environmental policy, planning and management agencies are to consider the groundwater needs of ecosystems, they need to determine how much water can be taken from the environment before significant impacts occur.

An example of a groundwater-dependent ecosystem is the *Banksia* woodland communities of the Swan Coastal Plain. The vegetation of these communities needs groundwater for transpiration, growth and seedling establishment. Of particular importance is whether there is a seasonal difference in the requirements of plants in these communities for groundwater. Recent research at Edith Cowan University has identified seasonal changes in the importance of groundwater as a water source to these communities. During winter and spring (wetting phase of the year; see Figure 1), the high rainfall wets the soil zone (brown shading) providing lots of water to the Banksia tree. The water in this zone can account for up to 80% of the total water used by the tree. Only a small amount of the water used by the tree (20%) comes from the groundwater table during this time. During the drying phase of the year (summer and early autumn; see Figure 2), rainfall decreases meaning there is less water available in the soil profile. This means that groundwater becomes an important water source to the Banksia tree accounting for up to 70% of its total water use.

This season of high groundwater use by *Banksia* is when plants are most susceptible to groundwater drawdown (lowering of the watertable) due to pumping (abstraction) for human use. Lowering of the watertable beyond the reach of the deepest roots removes the primary source of water to the trees. Water remaining in the soil profile then becomes the sole water source but is often not enough to meet the tree's water requirements for a long period of time (1-2 months). However, by this time, autumn rainfall usually recharges the soil profile and by late winter, groundwater is also recharged and the watertable rises again, resetting the plant water sources for another seasonal cycle. If insufficient rainfall occurs, or groundwater abstraction increases, watertables may not rise, again leaving the soil profile as the only water source. In this case, the Banksia trees will experience significant water stress by the end of the following summer and could die as a result.

By identifying the seasonal changes in water source use by *Banksia*, Perth's water resource management agency is now able to plan for groundwater abstraction to occur during times of the year when threats to the groundwater-dependent vegetation are minimal, and ensure that during spring and early summer the watertable is at a level which can be accessed by *Banksia*.

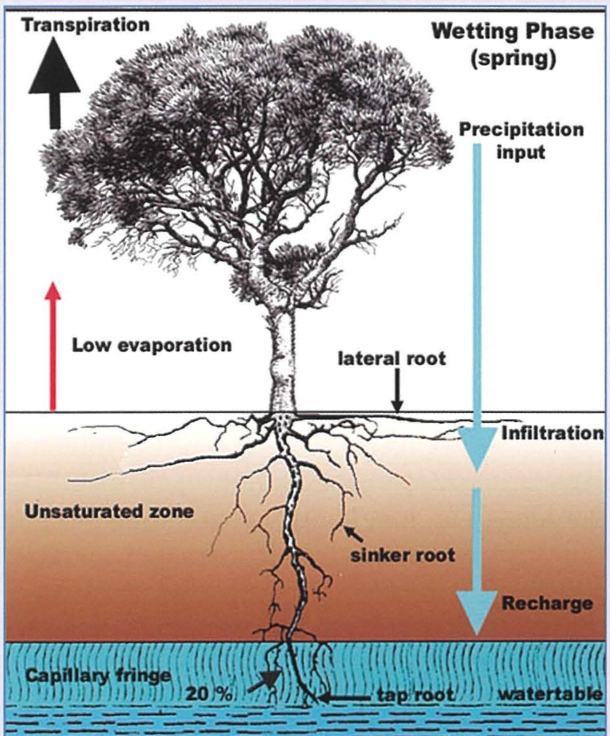


Figure 1
In Winter/Spring Banksias access about 20% of their water needs from groundwater.

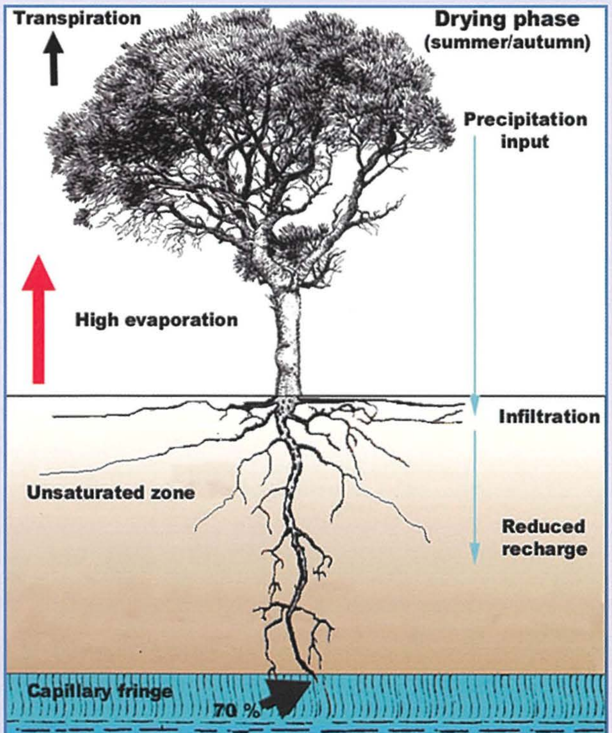


Figure 2
In Summer/Autumn Banksias access about 70% of their water needs from groundwater.

Impacts of Declining Groundwater Levels on Perth's Native Vegetation

Phillip Groom and Ray Froend

A large proportion of the total water usage (~70%) for metropolitan Perth is obtained from groundwater resources which is used to supply domestic, industry and agricultural water requirements. In order to protect the quality of this groundwater resource, several development restrictions over the centre of the largest shallow aquifer close to Perth (Gnangara Groundwater Mound) are in place, including management of large areas of land supporting native Banksia woodland and wetland vegetation. Removing groundwater (known as abstraction) ultimately lowers the water table, and may have a detrimental impact on ecosystems dependent on shallow groundwater. The effects of groundwater abstraction on groundwater levels depends on the abstraction rates of individual bores, and the number, location and spacing of these bores. Potential impact of drawdown on groundwater-dependent vegetation ranges from gradual changes in plant community structure, to sudden and extensive vegetation deaths.

One of the most significant impacts of abstraction operations on native Banksia vegetation was observed in the summer of 1991, near groundwater production bore P50 in the Pinjar borefield, 35 km north of Perth. The combination of long-term regional groundwater level decline, two consecutive years of poor groundwater recharge (caused by below average rainfall), a falling groundwater table caused by groundwater abstraction (2.2 m decline within a year), and high summer temperatures (>40 °C) were all associated with a collapse in Banksia populations (20-80% of Banksia trees), and up to 64% reduction in understorey shrub populations near P50. Groundwater levels on the Mound have been gradually declining since the 1970s due to an overall downward trend in annual rainfall (groundwater recharge is entirely dependent on rainfall), and an increased reliance on groundwater for public and private water supply. This decline is considered to be the primary trigger for vegetation death within close proximity to groundwater production bore P50. Over a similar time period no significant decreases in the abundance of overstorey or understorey species were recorded at an area not influenced by groundwater abstraction. The inability to reduce leaf temperatures via transpirational cooling, whilst under considerable water stress

in response to high summer temperatures, was considered to have had a secondary effect on both understorey and overstorey species.

Because of the potential impact of the P50 production bore on the surrounding native vegetation, the annual abstraction quota was spread over the first three years of production (beginning in 1989) to enable the vegetation to acclimatise to a gradual lowering of water tables. It was unfortunate that successive years of poor recharge, in combination with groundwater abstraction, compromised the water requirements of overstorey and understorey species within this three year period. Such species may have already become acclimatised to the gradual reduction in long-term groundwater levels (an overall 1.6 m decline over 13 years at P50) prior to abstraction, and if abstraction had not occurred may not have displayed reductions in population size and vigour as groundwater levels continued their decline. Continued monitoring of groundwater levels, floristic composition and vigour of areas influenced by abstraction are essential for the long-term stability of Perth's native vegetation.

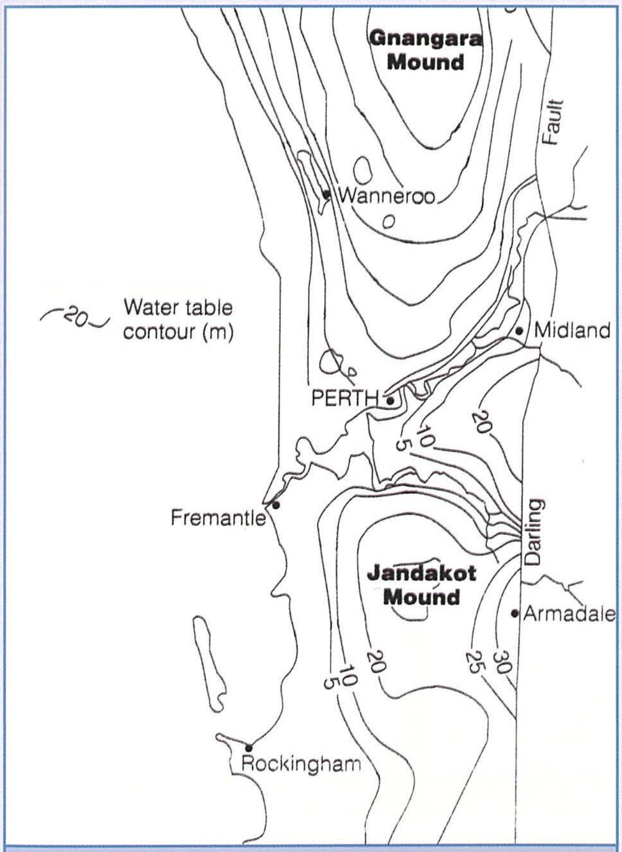


Figure 1
Perth has two major groundwater aquifers — the Gnangara and Jandakot mounds.

To prevent future summer deaths near groundwater abstraction bores, water levels of bores within close proximity to stands of native vegetation should be constantly checked for compliance with their predetermined environmental water provisions, particularly during successive years of poor recharge. Environmental water provision is the water allocation that will be provided to an environment, as determined by managers of water resources. However it is often difficult to determine an appropriate level of water provision which will prevent long-term changes in community structure. If water levels are likely to breach these water provisions, the frequency of groundwater monitoring needs to be increased, and in the worst case scenario, pumping from local production bores should cease until sufficient groundwater recharge occurs.

River Restoration

Rosanna Hindmarsh

European settlement in Australia brought with it European farming techniques. These techniques caused considerable damage to the fragile Australian environment. One of the problems that has occurred is the loss of vegetation on the floodplains and the areas fringing the river channels. The area of fringing vegetation is referred to as the riparian vegetation.

THE NATURE OF THE PROBLEM

Clearing of the floodplain and riparian vegetation was done to provide summer grazing and access to water for livestock. This has resulted in:

1 Damage to the river banks and loss of habitat.

2 Undercutting and bank collapse.

3 Increased sediment in the waterways that degrades aquatic habitats.

4 Changes in flow patterns leading to increased risk of flooding.

5 Poor water quality.

Further damage to the land occurs when hilltops are cleared, particularly in steep river valleys. This increases the amount and speed of the water as it moves across the landscape causing extensive erosion. A large amount of organic material and soil is also carried into the waterways. An over supply of nutrients in the water can lead to eutrophication and toxic algal blooms. This can also reduce the oxygen availability in the water. Poisoning and lack of oxygen then leads to the death of aquatic organisms.

THE IMPORTANCE OF RIPARIAN VEGETATION

A well vegetated riparian zone that is wide enough will:

1 Help the stream bank to resist erosion.

2 Filter out nutrients, sediments and organic material washed off the paddocks.

3 Reduce the ability of exotic weeds to establish themselves.

4 Provide shade over the waterway to reduce excess algal growth.

5 Maintain healthy terrestrial and aquatic ecosystems.

THE PROCESS OF RESTORATION

Community recognition of unsustainable agricultural practices usually results in the formation of a catchment group to find solutions. By working together, the group develops a management plan to identify the problems. Once identified, the group then lists the actions needed to overcome these problems. The actions are then placed in order of priority. The cost involved in undertaking each action is calculated and supporting funding obtained to allow the work to be completed.

AN EXAMPLE OF THE PROCESS

Within the Wannamal catchment, 100 kilometres north of Perth, most of the landholders have come together as a catchment group. They formulated a management plan, sought and received extra financial support and prioritised their on-ground actions.

One part of their plan was to restore the lower part of the Udumung Brook, a west flowing tributary of the Brockman River.

The process involved:

1 Surveying the river channel to establish how much water it carried, the parts of the channel where active erosion was occurring and the best positions to construct in-channel structures.

2 Collecting the resources necessary.

3 Constructing a stock crossing hardened with rocks that gives livestock access to watering points while reducing trampling and erosion of the bank.

4 Constructing riffles to slow the water down, redirect the flow away from eroding banks, and create habitats for aquatic animals.

5 Fencing both sides of the waterway to prevent stock access to the river, and encourage regeneration of riparian vegetation.

Managing the Acidity of Abandoned Water-Filled Coal Mines

Mark Lund and Scott Thompson

In Australia, the holes created by open cut mining are set to become some of the country's largest and deepest lakes. Muja coal pit in Collie (Western Australia) will eventually create a lake that is 200 m deep and about 400 ha in area.

In Collie, Western Australia's main coal mining region, several coal pits were abandoned with no rehabilitation following a dispute between the mining company and the state government. These pits flooded creating new lakes. One of these, Stockton Lake, is a popular area for water skiing and boating. In the summer of 1994/95 the lake was closed to the public when it became too acidic (pH dropped below 4.5). Chemical treatment of the lake to increase the pH proved unsuccessful. In winter 1995, the pH had returned to safe levels and the lake was reopened. This stimulated both industry and government agency interest in conducting research into the voids. Dr Mark Lund and his research team (Scott Thompson and Sarah Brown) at the Centre for Ecosystem Management at Edith Cowan University (ECU) joined a collaborative Australian Coal Association Research Program Grant funded project with mining companies, government agencies and Curtin University to examine final void water quality enhancement.

Dr Lund's research focussed on understanding some of the physical and chemical processes

occurring within three of these lakes. The aim is to produce strategies to reduce acidity inside the lakes using a biological approach. This was to be achieved by encouraging a range of biological processes normally found in natural lakes and using them to reduce acidity.

The quality of water in the Collie mine lakes is generally good but too acidic to support a normal lake's biodiversity. In this regard the lakes are closer to swimming pools than natural lakes.

WHERE IS THE ACIDITY COMING FROM?

The main source of acidity in the lakes is runoff from nearby overburden dumps. Overburden is the material that covers the ore or, in this case, coal. It must be removed to extract the coal. On exposure to water, oxygen and bacteria, some minerals within it can be oxidised to form sulfuric acid. This process generally results in high concentrations of iron and sulfate in the lake, but in Collie it appears that they rapidly disappear into the lake bed.

WHY HAVE THE COLLIE VOIDS REMAINED ACIDIC FOR 40 YEARS?

Evidence from overseas suggests that mine lakes with a pH range between 3 and 5 will start to become less acidic over time as they accumulate organic material. This has not occurred in the Collie lakes as there was no rehabilitation of overburden dumps to create a suitable environment for sulfate reducing bacteria in the voids. This approach has been successfully used to treat acidic streams. Laboratory and field trials found that there was an initial reduction in acidity but this was due to neutralisation by the organic material rather than through bacterial activity. A trial using cow manure resulted in a prolonged reduction in acidity. This was attributed to the high concentrations of phosphorus in the manure. Phosphorus is found in the voids at extremely low concentrations and adding it in conjunction with organic matter stimulates algal growth, which in turn increases biodiversity. Increased biodiversity helps to stabilise the lake and reduce acidity.

How can this research be used to prevent this problem in the future? The ECU team recommends that as much organic material as possible be left in the shallow areas of the new lake. The type of organic material is probably not important. One possibility is that the upper slopes (which are usually contoured for safety reasons) are planted prior to flooding to 'grow' the organic matter. Other possible sources of organic matter include mulch, sawdust, hay, wine lees, manures and sewage. Naturally, consideration would have to be given to the proposed end use of the void and possible health and safety issues associated with some of these materials. The team suggests that fertilisers are also added to encourage algal growth.

The team is one of the founding members of the Centre for Sustainable Mine Lakes, a Government, University and Industry collaborative project and will continue this work into the future.

Acidification of Wetlands

Kelli O'Neill

Wetlands are home to a wide variety of plants and animals from tiny bacteria and invertebrates to frogs, turtles, birds and fish. A wetland is any area of land that is seasonally or permanently wet. Examples of wetlands are ponds, lakes and swamps.

Acidification (low pH) of wetlands is a worldwide problem leading to water quality decline and loss of biodiversity. The acidity can be toxic to some plants and animals causing deaths and disease which can ultimately lead to changes in the food chain.

Wetlands can become acidic in various ways. This case study focuses on acidification due to acid sulfate soils. Acid sulfate soils (ASS) are soils containing iron sulfide or pyrites (FeS_2). When these soils are exposed to atmospheric oxygen (i.e. the soils are dried) they oxidise. If water is present after oxidation sulfuric acid is produced which lowers the pH of the water making it acidic.

There are some wetlands on the Swan Coastal Plain that are seasonal meaning that they partly dry in summer due to evaporation and

decreased groundwater levels (lots of wetlands are surface expressions of the groundwater table). They become wet again when it starts to rain in autumn.

One seasonal wetland, Lake Jandabup (22 km north of Perth's city centre) became acidic in 1998. Also at this time: (a) macroinvertebrate species such as small crustaceans, water snails and some types of worms disappeared or declined in number, and (b) there were increases in acid tolerant species such as water fleas, corixid beetles, larval midges and larval mosquitoes.This indicated changes in the community structure of the wetland.

Research was undertaken at Edith Cowan University to find out why the lake became acidic. It was discovered that the decline in pH was caused by pyrite oxidation during summer and when the lake became wet again, following rain, acid was produced.

Lake Jandabup is not always acidic. Usually wetlands can counteract any acid produced through what is called buffering. What makes this event different is that over a number of summers (between 1996 and 1999) the lake dried for longer than it normally would. It is thought that this prolonged and extreme summer drying caused more pyrite oxidation and lowered the buffering capacity of the wetland, which in turn caused the pH of the lake water to decrease.

To decrease the risk of acidification we need to reduce wetland drying as this will prevent pyrite oxidation. Remember that pyrite needs atmospheric oxygen to be oxidised and if water covers the sediment less oxygen can reach it.

We can reduce wetland drying by pumping groundwater into it, this is known as artificial maintenance. Also, we need to use our bore water wisely, as taking too much groundwater can cause the wetland to become unnaturally dry.

The problem is that the wetland is naturally seasonal and other plants and animals that live there like it to be alternately wet and dry. A compromise needs to be found between keeping the wetland wet and letting it dry.

The future of Lake Jandabup is promising. As of winter 2000 the pH was at near 'normal' levels and missing macroinvertebrate species are returning to the lake. For various reasons, which can not be explained here, the lake has at least temporarily recovered from the acidification. But, who knows what the future will bring?

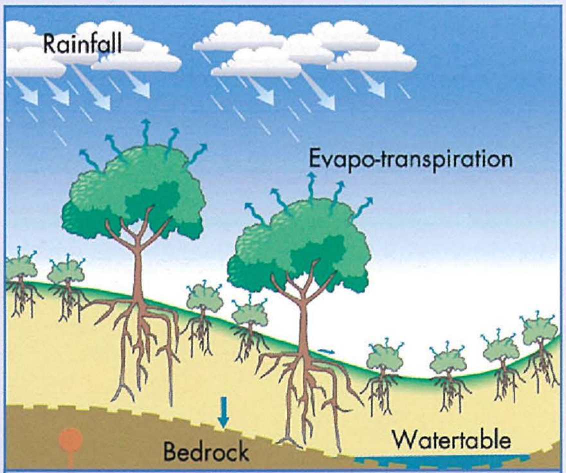
Research by Dr Pierre Horwitz and Ms Bea Sommer first detected the acidification at Lake Jandabup. An Honours study by Kelli O'Neill, supervised by Dr Pierre Horwitz and Dr Mark Lund, was undertaken to determine the cause of the acidification.

Salinity in South-western Australia

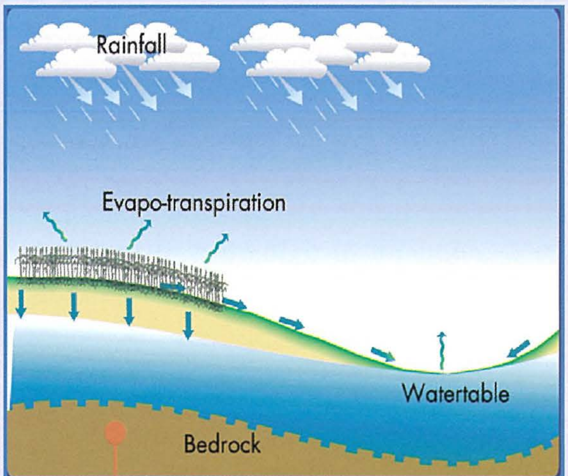
Beatrice Franke

Salinity is a complex problem facing Western Australians. Put simply, salinity refers to the presence of salt in surface and near-surface soil, and in water. There are different types of salinity:

1 Primary salinity refers to areas where soils contain higher than average concentrations of salts as a result of normal processes that occur over geological time in the landscape. These processes include deposition by wind and rain, weathering from parent rock, transportation by surface water flows, and accumulation in evaporation basins. The best examples of primary salinity are the extensive salt lakes in the arid and semi-arid regions of the state, believed to have been saline for thousands of years.



Deep-rooted perennial plants use large quantities of water and help to keep the watertables down



Shallow-rooted annual plants use smaller quantities of water, allowing watertables and salt to rise to the surface

Figure 1
Salinity is caused by rising watertables that transport salts from deep in the soil and bring them to the surface

Adapted from "How Salinity Occurs", Department of Agriculture, Western Australia

2 Secondary salinity refers to soils that have become saline as a result of European land management practices. Secondary salinity can develop in areas where agricultural crops are being irrigated (irrigation salinity), or in areas where farmers depend on seasonal rainfall to raise their crops and pasture (dryland salinity).

Both irrigation salinity and dryland salinity occur as a result of rising groundwater tables and evaporation at the surface of the soil. Irrigation salinity occurs in irrigated areas where drainage is inadequate. Irrigation schemes can cause groundwater tables to rise due to leakage from dams and canals, the over-application of water and inadequate drainage.

Dryland salinity is caused mainly by clearing of perennial, deep-rooted, native vegetation and its replacement with shallow-rooted, annual crop and pasture plants. Crops and pasture have less extensive root systems and use less water than native vegetation. This results in more water entering groundwater stores and rising water tables, rising on average by 20 cm per year in agricultural areas of Western Australia. Dryland salinity, in particular, is accompanied by inundation where areas become flooded, and this waterlogging is sufficient to smother tree roots and deprive them of oxygen.

As the groundwater rises it dissolves salts stored in the soil profile and transports them towards the soil surface or along natural drainage channels to inland water bodies. Near the soil surface the water evaporates, leaving behind increased salt concentrations or, in the most severe cases, surface salt encrustations. High concentrations of salt in the soil are lethal to most plants, and only plants adapted to high salt levels are able to grow successfully in saline soils.

Groundwater carrying high levels of dissolved salt also drains into inland water bodies such as lakes, swamps and rivers. Here the higher salinity levels affect the water quality and the survival of aquatic plants, thereby reducing food resources and changing habitats. This in turn severely affects survival rates of resident animal species. Potential biodiversity (plant and animal species) losses in salinity-affected areas of Western Australia are extremely high. Up to 80% of privately owned and up to 50% of public lands supporting remnant native vegetation in Western Australia are believed to be at risk from salinity over the next 100 years - this is in addition to other threats faced by these areas such as grazing and weed invasion. It has been estimated that as many as 1500 plant species will be subjected to the effects of salinity and associated waterlogging, 450 of which could face extinction.

More on Salinity: multiple consequences of change in agricultural ecosystems

Beatrice Franke and
Pierre Horwitz

By early 2000, 1.8 million hectares of Western Australia's south-western agricultural region were affected by salinity. We now know that salinity levels in streams draining cleared catchment areas have increased since monitoring began, and all the larger river systems of the south-west can now be classified as saline, marginally saline or brackish. In addition, large areas of agricultural land are being lost as salinity increases in agricultural districts. The impacts of waterlogging and salinity will also affect infrastructure including roads, bridges and buildings. The costs in lost agricultural production and infrastructure repair and maintenance due to salinity-related effects could rise to several billion dollars per annum by 2050.

These changes will come at a social cost to rural communities. Communities have to cope with reduced drinking water quality, reduced productive agricultural land and loss of, or damage to, infrastructure. Losses in agricultural production may put farmers into financial difficulties, which may result in the loss of a family property, even forcing people to move from the area. A smaller local population leads to less demand for services and facilities such as banks, bakeries and hospitals, and these may move to larger regional centres. The incidence of stress-related health issues is likely to increase and family stability may be affected. In addition there may be increases in the populations of parasites and water-borne disease organisms in areas of waterlogged soil.

Where clearing has occurred and/or where soil salinity has reached concentrations high enough to cause the death of most plants, the soil is exposed to erosion. When plant roots are no longer there to help bind the soil, strong winds and surface water flows will remove it and deposit it elsewhere. This can result in the sedimentation of lakes and rivers - the deposition of sand and silt - adding to water quality problems and changing the physical shape of these water bodies, such as their depth and width. These 'new' sediments bring contaminants with them such as residual fertiliser, herbicide and pesticide compounds. Sediments may be carried many kilometres down-stream and cause further problems in near-coastal marine environments like estuaries and seagrass beds, and even coral reefs in Northern Australia, thereby also impacting on resources that form the basis for the tourism and fishing industries.

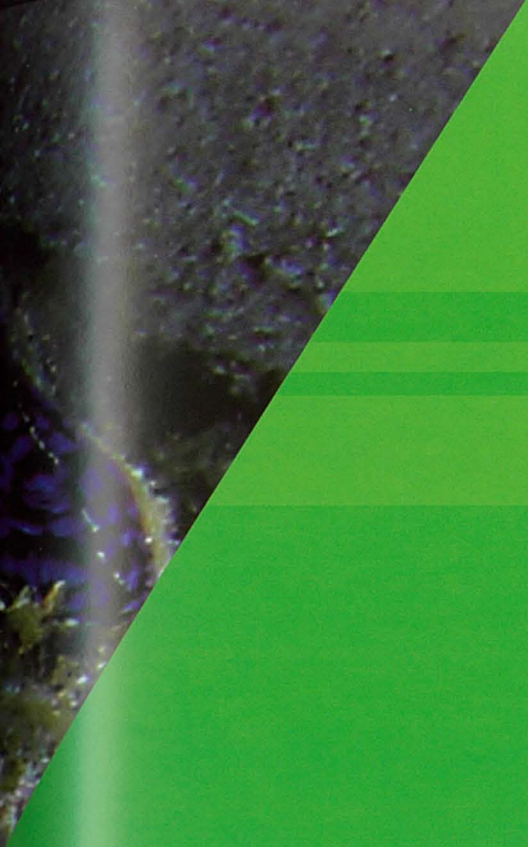
The clearing of vast areas of South-western Australia for agriculture and subsequent rise in water tables can result in other problems in addition to increased salinity. Seasonal cycles of waterlogging and drying out of soils and artificial draining of waterlogged areas can start a series of chemical reactions in some soil types, such as soils containing pyrites. These chemical reactions can result in the production of sulfuric acid, resulting in the acidification of waterways. When the acids are leached out of these soils and enter lakes and rivers, they can have a devastating effect on aquatic ecosystems. High levels of acid (low pH) can be potentially toxic by mobilising heavy metals and poisoning aquatic organisms including fish, even poisoning humans in severe circumstances.

Salinity therefore acts in concert with a number of other environmental and social issues for rural Western Australia.

Efforts to deal with salinity have largely concentrated on the protection of native remnant vegetation, revegetation with native plant species and the building of drainage systems. Clearing controls have been put into place and the use of improved soil management practices is strongly advocated. Research into ways to identify, monitor and manage the many effects of salinity is continuing. Many efforts are under way to identify and develop alternative crop and pasture species that can survive in more saline conditions and/or have high water-use characteristics. These include timber and eucalyptus oil producing species and potential fodder plants, and many trials are under way to integrate these species into farming systems without abandoning the traditional mainstays of wheat, sheep and dairy production. Investigations into groundwater flow systems and their management are also under way.

Judging whether or not these activities are indeed effective is not an easy task. Arresting or even reversing the development of salinity is likely to take a very long time, if reversal is possible at all. We may find that we have to 'adapt' to and 'learn to live' with salinity, at least to some degree, by making productive use

of the salt, salt water and salt-tolerant plant and animal species. Above all, we need to learn to view salinity not as an isolated problem, but as one of a number of inter-related issues in Western Australian agricultural ecosystems. And when making decisions on how to deal with these issues, we must also keep that inter-relatedness in mind.



Australia's Marine Environment: a nation's future

Harry Recher

One of the most active study programs in the Environmental and Biological Sciences at Edith Cowan University is about our estuaries and coastal marine waters. Almost 90% of Australians live in the coastal zone, the part of the landscape that has direct influence on the ocean. Because of this, our behaviour on land, as well as in the oceans and estuaries, can affect the health and productivity of our marine waters. Staff and students study the ecology of marine environments and how they are affected by everything from recreational divers to mining and pollution. Much of this work focuses on the important and productive seagrass beds of Cockburn Sound near Perth, but students also study marine life and ecology on Perth's marine reserves and at Shark Bay and Ningaloo Reef. Australia's marine resources are important for the nation's economy in many ways. Rock lobsters and abalone are lucrative export commodities, while Western Australia's pristine coast line sustains important and growing tourism based industries. When the potential for aquaculture is added to this, the career opportunities in marine conservation and management are virtually limitless. Marine and biological studies at Edith Cowan University provide a solid foundation for developing a career in the marine sciences with opportunities to work in some of the most beautiful environments remaining on Earth, as well as studying animals as exciting as dugongs and sea horses.

Can Sea Creatures Tell us if the Ocean is Polluted?

By Lea McQuillan

More than half the world's population lives within 100 km of a coastline. Australia's population is concentrated mainly along the coast and as coastal zones become more densely populated, coastal water quality will suffer, wildlife will be displaced and shorelines will erode.

These problems occur as a result of run-off from agriculture, metals from factory wastes, sewage discharged into the ocean, petroleum from oil spills and boat use, run-off from residential storm water drains, over-fishing and habitat destruction from trawlers.

How can we tell if there is a problem before the problem gets too big? That is, how can we identify the small changes before big changes occur? Monitoring the ocean can look at any changes in the animals and plants as a result of these problems.

Chemical analysis of the water and sand of the ocean will tell us if pollution is present but it can not tell us if the pollutants are sufficient to have a negative effect on the plants and animals of the ocean.

Thus the use of 'indicator' plants or animals is possibly a better way to study the impact of pollution.

To be a good indicator a plant or animal must be widespread, easy to find and identify, abundant and have an abundancy that is susceptible to

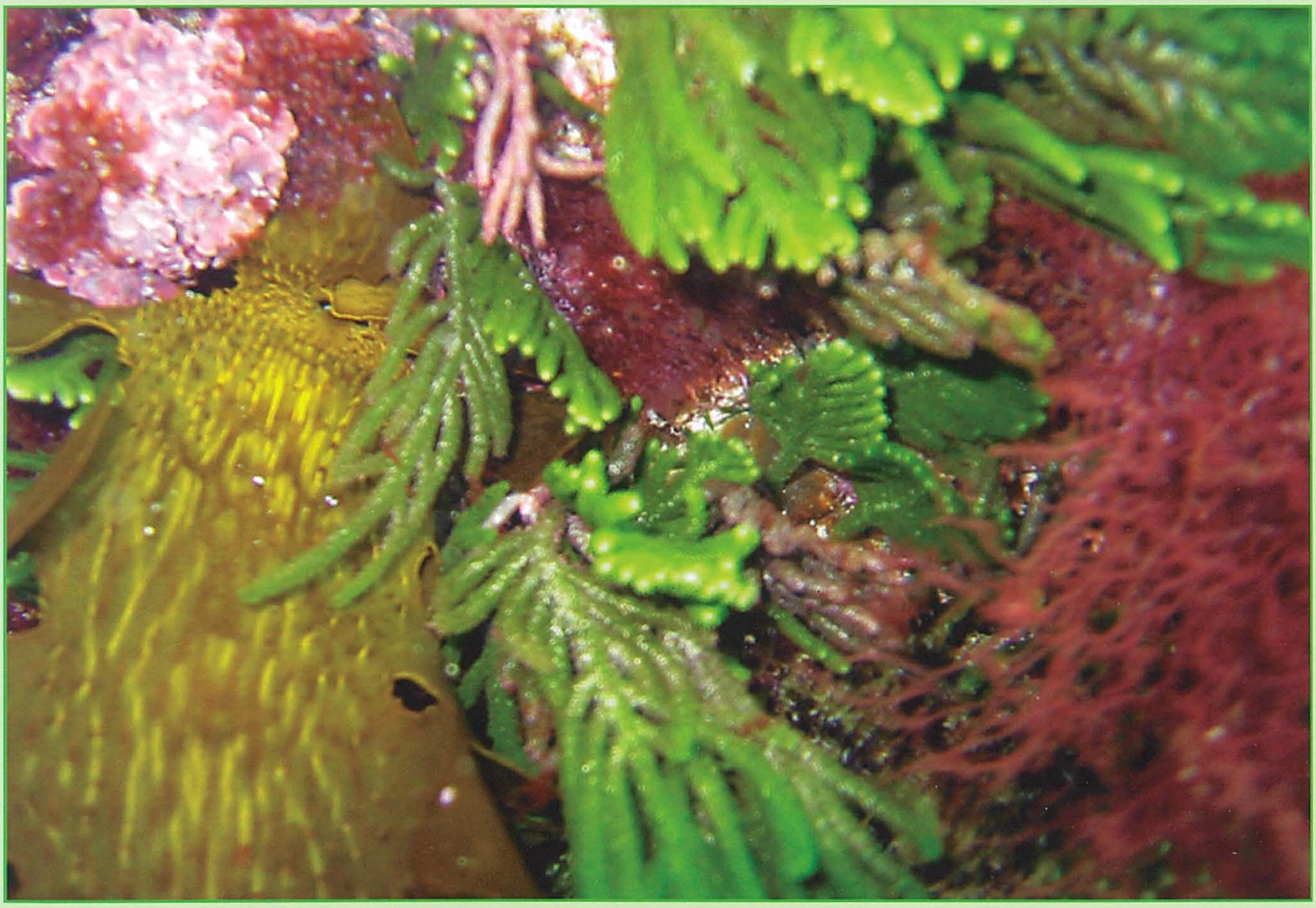
pollution, and should not be mobile.

Types of plants and animals that have been used as indicators of pollution include seaweed, mussels, butterfly fish and sponges. Some of these plants and animals meet all of the characteristics of a good indicator but some only meet a few.

Algae (seaweed) have been known to be influenced by pollution, where the brown and red seaweed tend to die off and the green seaweed takes over. Thus the pollution causes alterations to the species assemblage. Seagrass has also been used as an indicator plant. Seagrasses have been known to die off when exposed to high levels of pollution.

Mussels have been used for some time as indicators of pollution in America. Mussels accumulate heavy metals and petroleum in their bodies and thus can be used to indicate the level of pollution in the ocean. Butterfly fish have been used as indicators of the health of coral reefs. Butterfly fish are very sensitive to pollution and thus are not common in polluted coral reefs.

Recently scientists have begun to use sponges as indicators of pollution. Studies have shown that a little pollution leads to more variety of sponges, but at high levels of pollution only a few sponge types are able to survive. Using plants and animals as indicators of pollution is still a relatively new science.



Impact of Seagrass Loss on Fish Stocks

Glenn Hyndes

Seagrasses are flowering plants that live in marine and estuarine environments. They can form extensive meadows that provide important habitats for many fish species in coastal waters of the world. Part of the benefit of seagrasses to fish populations is the shelter that they provide for fish to hide from predators, as well as the large numbers of small invertebrates that they house and which are important food for many fish species. It is suggested that the combination of these benefits results in less fish being eaten by bigger predators and fish having access to more food, and therefore, more fish surviving and growing faster.

Western Australia has a high diversity of seagrasses, which form extensive meadows throughout its coastal waters. Since large areas of seagrass are located close to the coast, they are vulnerable to human impacts. Excessive nutrient loading in estuaries and sheltered marine embayments has led to massive seagrass loss in parts of Western Australia. In addition, dredging activities and coastal developments have resulted in seagrass loss. The impact of such losses on fish stocks is likely to be high. This is highlighted by the declines shown in catches of King George whiting following massive seagrass loss in parts of south-eastern Australia. It is therefore critical that we understand how seagrasses influence fish stocks in our coastal ecosystems.

Researchers at the School of Natural Sciences at Edith Cowan University are carrying out studies to examine the importance of seagrass ecosystems to fish. Earlier studies have shown that fish assemblages differ among the different types of seagrass meadows that occur in our coastal waters. Figure 1 shows that the number of species and density of fish in seagrass are greater than those found over bare sand. More interestingly, the number of species and density of fish differ

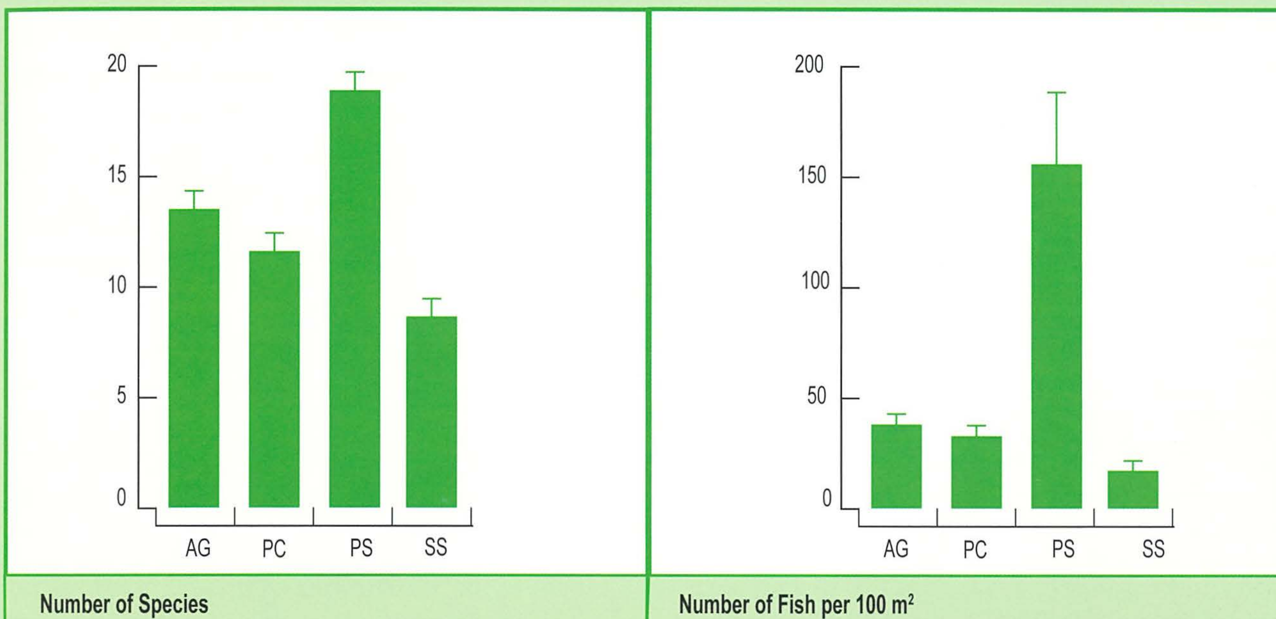


Figure 1
Mean number of species and densities of fish found in three seagrass habitats, namely *Amphibolis griffithii* (AG), *Posidonia coriacea* (PC) and *Posidonia sinuosa* (PS), and unvegetated sand (SS).

markedly between three seagrass habitats. This means that the scale of the impact on fish assemblages through seagrass loss will depend on the type of seagrass that has been lost. There is therefore a need to gain a greater understanding of how these losses will impact our fish stocks, particularly the species that we like to see on our dinner plates.

Protecting Our Marine Biodiversity: ecology and modelling

Paul Lavery

Western Australia is blessed with a remarkably diverse flora and fauna, on the land and in the sea. Unfortunately our marine biodiversity is not as easy to appreciate as that on land, but it is no less impressive. Among that marine biodiversity are the seagrasses, a group of flowering plants that have re-invaded the seas. Western Australia has the highest diversity and some of the largest meadows of seagrass in the world, with about half of the world's 50 species. Seagrasses have important functions, including the provision of habitat for other organisms. The complex structure of seagrass meadows provides an ideal environment for many species to shelter from predators, or to find food.

Western Australia is also home to some of the most significant losses of seagrasses known to have occurred in the world. Up to 97% of seagrass beds were lost from Cockburn Sound by the late 1970s, while 46% to 66% of seagrass meadows were lost from Princess Royal and Oyster Harbours in Albany during the 1980s. These losses were due to nutrient enrichment which increased algal growth and starved the seagrasses of light. Today, seagrasses on Success Bank, immediately north of Cockburn Sound, are under threat from mining, which removes the seagrasses while dredging out carbonate-rich sands. Elsewhere, in the Sound itself, marine construction threatens meadows.

Managing Australia's seagrass and other marine biodiversity is a task made doubly difficult by the poor documentation of our underwater biodiversity and our poor understanding of the processes that influence it. What is reliably known is that it is under as much threat as our terrestrial biodiversity, and from much the same processes - habitat loss and pollution.

Working on Success Bank and in Cockburn Sound, researchers at Edith Cowan University have been documenting the biodiversity of different types of seagrass meadows. That

information is being used in computer models to help minimise the impacts of human activity on that biodiversity. A common assumption, until recently, was that most seagrass ecosystems functioned in much the same way. Our research has challenged that assumption. Not only do different seagrasses form meadows which support different biodiversity, but the way that biodiversity is organised within the ecosystems differs. For example, *Amphibolis griffithii* seagrass meadows on Success Bank support up to 92 species of algae, 122 species of large invertebrates and 88 species of fish. In comparison, *Heterozostera tasmanica* seagrass meadows were found to support 34 species of algae, 100 species of large invertebrates and 98 species of fish. We also know that biodiversity changes between places, but the way in which it changes can vary between seagrasses.

Our research into seagrass biodiversity is allowing us to make much better estimates of the impacts that human activities (such as mining or port development) might have on marine biodiversity. Using Geographical Information Systems (GIS) together with our understanding of what is found in seagrasses and how it is distributed, we are able to produce maps of where different types of organisms are found in a marine area. Using the models avoids the need to undertake time-consuming and expensive surveys, and allows us to identify areas potentially important to the overall biodiversity of an area and in which human impacts should be avoided.

Figure 1 shows the species diversity which has been modelled to occur on the sand banks off Fremantle, and that which we predict would occur if the area inside the blue rectangle were to be mined for carbonate sand. Information such as this has been used by industry and the Environmental Protection Authority to make decisions about how much impact is acceptable and, if allowable, where it should occur to minimise the impact.

Our research at Edith Cowan University is helping to keep Success Bank and other seagrass ecosystems healthy and something we can all enjoy, now and in the future.

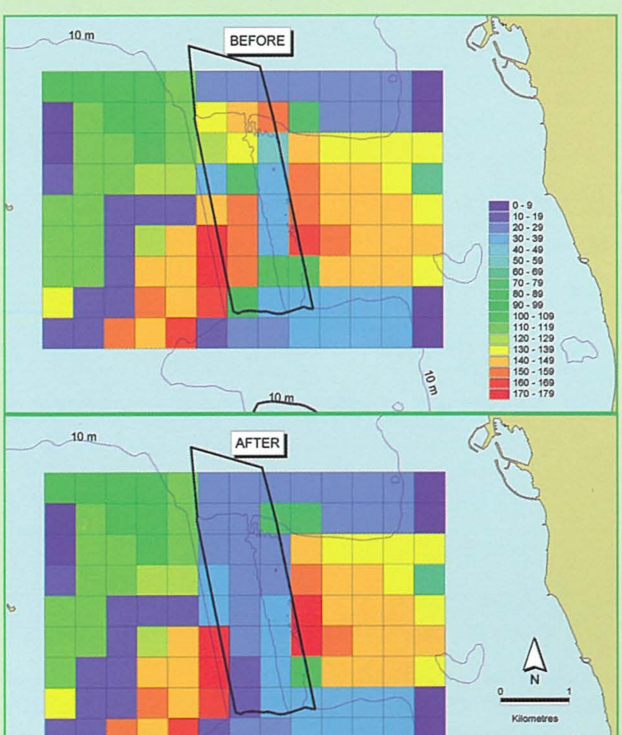


Figure 1

Maps showing the predicted species richness for Success Bank before (top) and after (bottom) mining in the rectangular area. The maps were produced using a combination of real biodiversity data gathered in surveys and GIS models to predict what would occur in areas that were not sampled.

Seagrass Restoration

Rebekah Kenna, Glenn Hyndes and Paul Lavery

Seagrasses are highly specialised marine angiosperms, occurring in the nearshore environment. Australia possesses the highest diversity of seagrass species and the most extensive seagrass meadows worldwide. Seagrass meadows have been shown to provide important ecological and physical roles in coastal environments. They are therefore viewed as a critical link in the ecosystem function of many coastal landscapes, where they are important to fisheries, aquaculture and tourism.

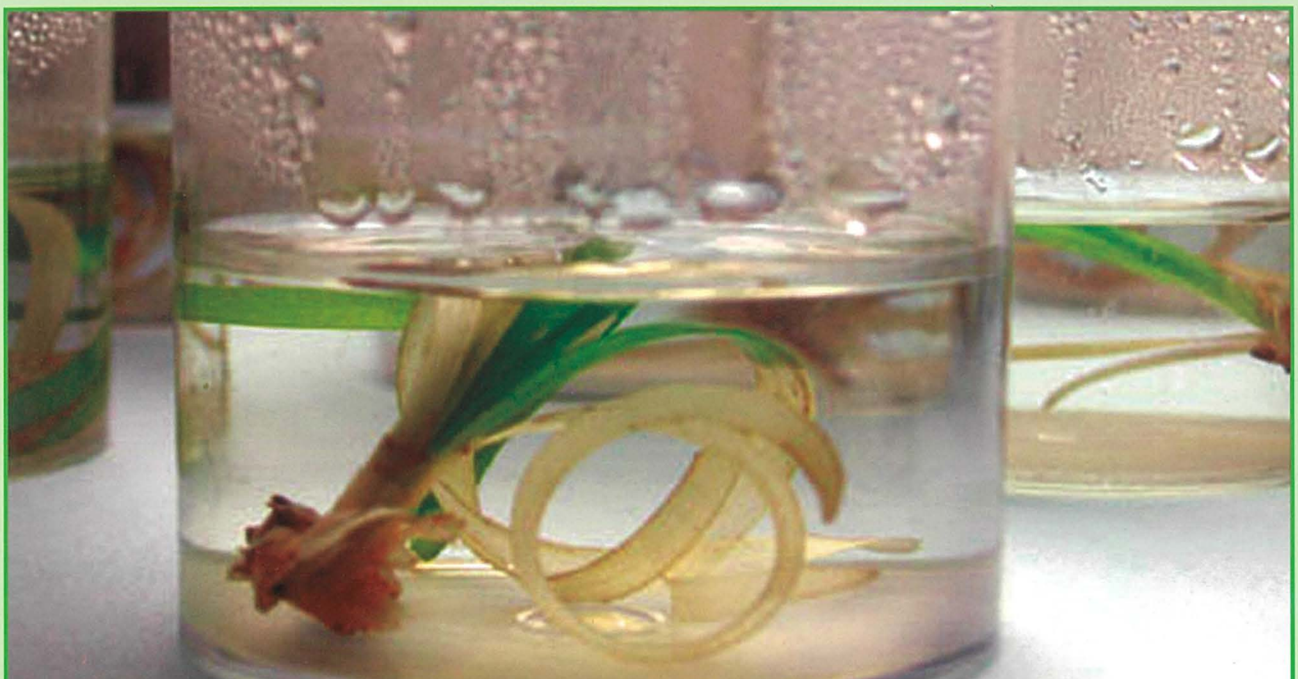
The important ecological role of seagrass in coastal ecosystems has led to concern over the significant decline in seagrass area over the last 40 to 50 years. Seagrass losses have been documented both on the local and international scale. It has been estimated that 450 square kilometres of seagrass has been lost around Australia. Numerous studies have directly linked seagrass losses to anthropogenic activities. Excessive nutrient loading has led to eutrophication, increases in algal growth, which has reduced the amount of light available to seagrass. This process has been recognized as the major cause of loss of seagrass meadow in estuaries and sheltered marine embayments. Seagrass loss has also resulted from increased sedimentation, dredging operations, boating activities and coastal developments such as marinas and harbours.

Awareness of the magnitude of seagrass losses and their slow recovery, together with a wide acceptance of their ecological value has triggered an interest in the restoration of seagrass meadows. Seagrass restoration is generally seen to improve, augment, or enhance areas that have lost seagrass, with the expectation that all aspects lost or damaged will improve with the return of seagrass and seagrass ecosystem function.

Numerous restoration projects, using different seagrass species, have been attempted with varying degrees of success. Successes have been achieved in putting back small areas of lost or damaged seagrass. However, some spectacular failures of seagrass transplanting have occurred. At this time, transplanting techniques have been tested sufficiently to allow small areas of certain species to be restored with reasonable assurance of creating or replacing seagrass cover. Today, seagrass restoration is still in its infancy with limited survival success been reported on large scales throughout the world.

Traditionally, seagrass restoration programs have judged 'success' as planting unit survival and changes to the physical structure of the transplants. However there have been few studies to evaluate the assumption that structurally restored seagrass meadows provide a concomitant recovery of all major ecological functions. Few restoration programs so far have emphasised the need to incorporate any other ecological functions in establishing goals and objectives in restoration programs. Yet it is the ecological functions performed in seagrass meadows that have underpinned a substantial portion of management initiatives in coastal areas. Currently there is a move across many fields in ecology to assess functional success of restoration programs as opposed to only survival success.

A study at Edith Cowan University is examining the restoration of ecological functions in transplanted seagrass meadows. The purpose of this research is to describe the re-establishment of major ecological functions in areas of transplanted seagrass, initiating a baseline on which seagrass restoration projects can be assessed. This will be achieved in a temporal study assessing the rates of function re-establishment and successional patterns of different function re-establishment for major ecosystem functions in a transplanted seagrass. An understanding of the re-establishment of ecological function in transplanted seagrass meadows is crucial to good management of our coastal ecosystems.



Tissue culture of seagrass in the laboratory

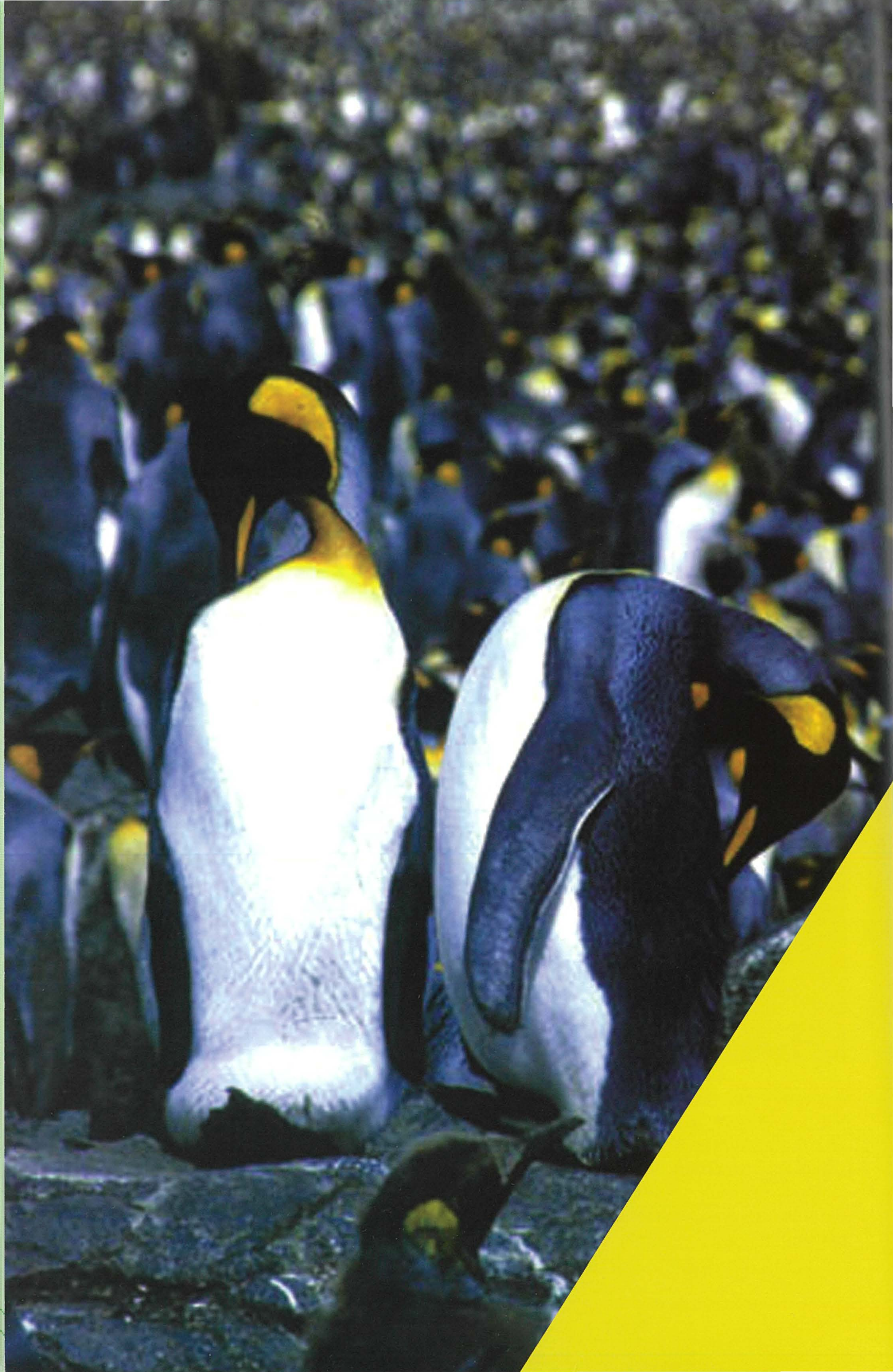
Our Southern Limestone Reefs: their place in our marine biodiversity

Beverley Van Elven

The coastline of Perth is fringed by a line of rocky limestone reefs that are home to an amazing array of marine plants and animals. The biodiversity of these reefs is important enough that some of our most important marine parks are declared mainly for their preservation. But the reefs not only provide a home for organisms growing on them, they also strongly influence the diversity in the surrounding ecosystems. One example of this is the seagrass meadows that grow close to our limestone reefs. One of the most important parts of seagrass ecosystems is the algae (or seaweeds) that grow on the leaves and stems of the seagrass plants, also known as epiphytic algae. Epiphytes are important primary producers, with this production serving as food for many fish and invertebrates. They are also important in nutrient cycling and are a major contributor to the biodiversity of seagrass ecosystems. Because of their ecological importance, the biodiversity of epiphytes is important; differences in the types of epiphytes can affect the types of ecological functions that different seagrass meadows perform. But what influences the biodiversity of seagrass epiphytes? Because seagrasses often occur in the vicinity of reefs, we proposed that the epiphytes present on these seagrasses would strongly resemble those present on the reef - that is, the reefs act as a source of biodiversity for nearby seagrass systems. To test this we performed two experiments. First, we collected the microscopic algal propagules (spores and

other microscopic reproductive material) in water above reefs and nearby seagrasses to see if the same spores were present at both sites. If they were, this could indicate that the spores being released by algae on reefs were travelling to nearby seagrasses and settling there. Second, we placed artificial seagrass, made out of plastic strips designed to look like real seagrass, on reefs and in seagrass near reefs and several kilometres from reefs. We then observed what algae grew on the artificial seagrass to see if those near reefs were more similar to the algae on reefs than those well removed from reefs. We found that proximity to reef did influence the seagrass leaves. Reefs can do this in many ways, but most probably by providing a source of algae that can recruit to nearby seagrasses. This influence of reefs on biodiversity in other ecosystems has important implications for managing our marine environment. In particular it has implications for the design of marine parks. If parks are being designed to capture the whole range of biodiversity in an area, and the ecological processes that biodiversity performs, then it is important to include reef areas. However, our results show that it is equally important to include areas of different ecosystems that are both close to and far away

seagrass epiphyte assemblages. At sites near reefs, propagules in the water above seagrasses and the algal epiphytes growing on artificial seagrasses were very similar to those at the reefs. At seagrass sites well away from reefs, the similarity was much less. This suggests that reefs influence the types of epiphytic algae that reach seagrasses and subsequently grow on from reefs. This will provide a better chance of capturing the range of diversity present in a region. Research projects such as this one being undertaken at ECU, are increasing our knowledge of what our reef systems are and the important role they play in our complex marine environment.



Biodiversity

Harry Recher

Biodiversity is the variety of life on Earth. It means all the world's species from viruses to whales. But it is greater than that. Biodiversity embraces all the genetic variety of all the populations of all the species on Earth including all the different kinds of plants and animals humans grow for food, keep as pets and use for transport. It is even greater than that and biodiversity can be used to embrace all the different kinds of people and their art, music and traditions. Biodiversity is what makes the world an interesting place in which to live. Without biodiversity every place would seem the same and daily existence could get quite boring. Making the world exciting is therefore one of the great values of biodiversity, but there are others. Almost all the things we use in life are derived from plants and animals - our food, clothing and the timber for our homes, as well as many medicines, are derived from living organisms. So is most of the fuel we use in cars and power stations to move us and our products about, and to provide energy for lights, heating and cooling. Coal, oil and natural gas are products of living organisms, as is the oxygen we breathe and many of the minerals we mine. Biodiversity is at the heart of recreation and tourism. Without biodiversity the world would be poorer and modern society would be impossible. We rely on other organisms not only for food, clothing and medicines, but a vast array of other organisms, many too small to see, keep our farms fertile and our forests and oceans productive. Conservation and environmental management is all about conserving biodiversity. At Edith Cowan University, the study of biodiversity and what it means to Australia's future is a key element of the environmental management and biology programs.

Soil Mites: the little things which run the world!

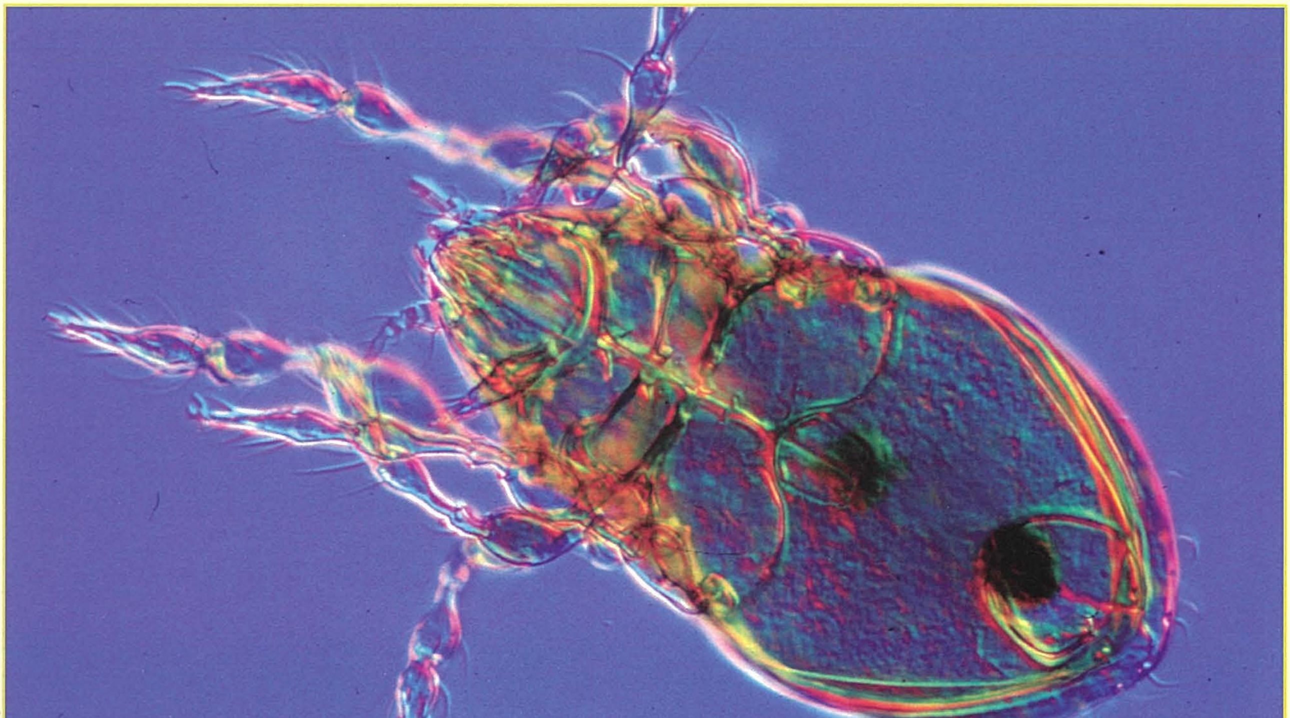
Adrianne Kinnear

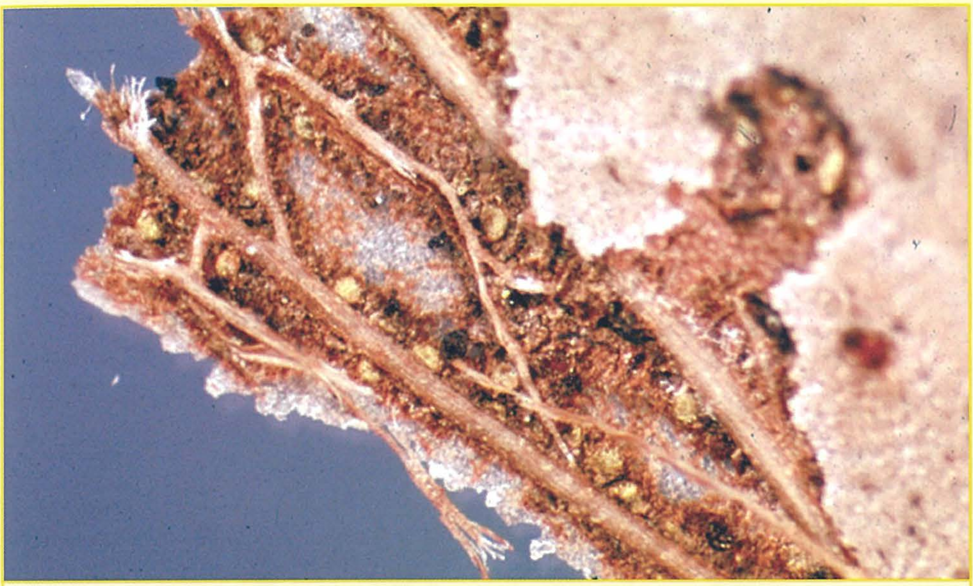
A leading biologist and author, E.O.Wilson, once described our invertebrate animals as "the little things which run the world". Nowhere is this more true than the tiny animals which inhabit our soils and leaf litter layers. The soil system is one of the most biodiverse of all our biological systems, rivalling even the rainforest in the number of species per unit area. Below-ground and out-of-sight, complete communities of herbivores, omnivores and predators interact with fungi and bacteria, to process the world's organic matter and keep ecosystems 'running'.

We can start by thinking about it as a diverse community of organisms, each with their own preferred 'living space' and all connected with one another by their feeding habits.

Decaying leaf litter provides the food resources for the soil community. Bacteria and fungi quickly colonise the dead leaf material, and with their powerful chemical enzymes, begin to break down the complex plant tissues. They grow over the leaf surfaces and, much like tomato sauce on a meat pie, make them attractive to the fungal and bacterial feeders next in the food chains (the roundworms, mites and springtails). In turn, these grazers and browsers of the soil system attract the predators such as spiders and centipedes.

We are all familiar with the earthworm, and its contribution to a healthy soil structure, but in between the mega-earthworm and the micro-bacterium is a huge array of animals we rarely hear about and which are part of the





Tiny faecal pellets of soil animals can fill the spaces of decomposing leaves, providing ideal food surfaces for the growth of bacteria and fungi.

reason for the soil's biodiversity. These are the middle-sized animals or 'meso-fauna'. A single footprint can cover up to 3000 individuals belonging to more than 50 species! Between 50 - 90% of these animals are free-living soil mites, tiny eight legged relatives of spiders and scorpions. We now know that if we prevent the mesofauna from participating in the decomposition of leaf litter, it can take between a third and a half as long again for the leaves to decay, and for nutrients to be released for plant growth. Yet they cannot produce any of the chemicals to break down leaf tissue like the bacteria and fungi. How do they influence the rate of leaf decay?

The mites and springtails enhance the activities of the bacteria and fungi in indirect ways as a result of their positions in the soil foodweb:

1 They are litter fragmenters, feeding on the leaves directly, or on the bacteria and fungi which colonise the leaf surfaces. The myriads of moist, tiny faecal pellets covered with gut secretions are particularly attractive to the bacteria and fungi which grow and feed on the pellets, increasing the rate of decay. The pellets act as miniature soil conditioners, and can assist the formation of a healthy soil structure.

2 Through their feeding activities, the mesofauna increase the biodiversity of the microorganisms, and control the abundances of the bacteria and fungi.

3 They act as transport vehicles for the microorganisms, moving bacterial cells and fungal spores through the soil's air spaces and along root channels.

4 They, in turn, are a food resource for the larger fauna.

Any kind of land use which affects the litter layer, degrades the soil structure or alters the soil chemistry affects the soil fauna. Agriculture, forestry and mining all lead to drastic reductions in the biodiversity of the soil fauna. But what might be the results of this reduced soil biodiversity? Does less animals mean poorer soils and disrupted decay processes?

These questions are not easy to answer and we still have a long way to go before we understand the effects of our impacts on the soil and litter communities. However, the research which has been done suggests that:

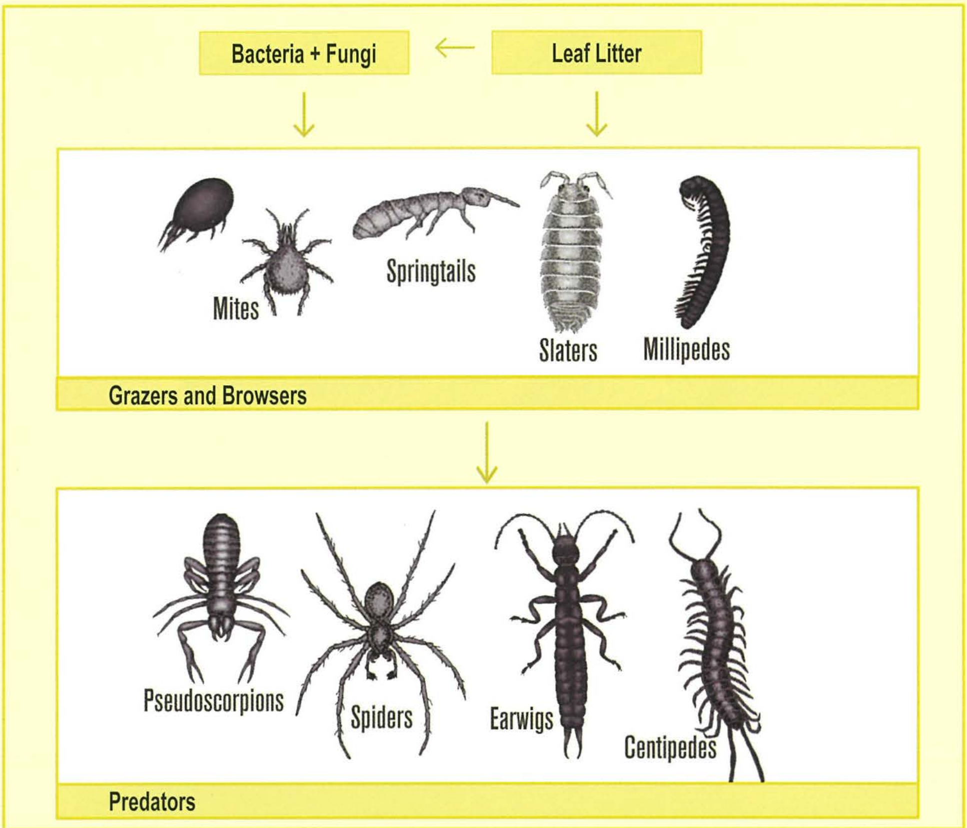


Figure 1

The Food Web

The feeding interactions of the soil organisms can be described by complete below-ground food webs.

1 The loss of earthworms and other large soil animals reduces the ability of the soil to absorb and retain moisture

2 The reduction in diversity of the smaller animals such as springtails and mites, and the fungi that occur when soils are cultivated or laid bare of vegetation, alters food webs in the soil. This can lead to reduced organic matter content, and increased leaching of nutrients into deep soil layers, far away from plant roots.

3 A reduced diversity of soil animals can result in reduced rates of decay of plant litter, with slower release of essential nutrients for plant reuse.

In the last two decades there has been a substantial increase in our awareness of the need to protect and maintain the soil biological communities. For example, many farmers now practise non-tillage, a method of not ploughing soil more than is necessary to sow and harvest. This is a direct result of increased awareness of the importance of the soil organisms and their role in maintaining soil fertility and productivity.

OVERGRAZING AND SOIL BIODIVERSITY IN WESTERN AUSTRALIA'S RANGELANDS

The shrublands of the Gascoyne region of Western Australia are important grazing lands for the sheep industry. A small shrub, the Gascoyne bluebush, dominates the landscape of these unique rangelands, and is a preferred food of sheep, particularly when annual grasses are unavailable.

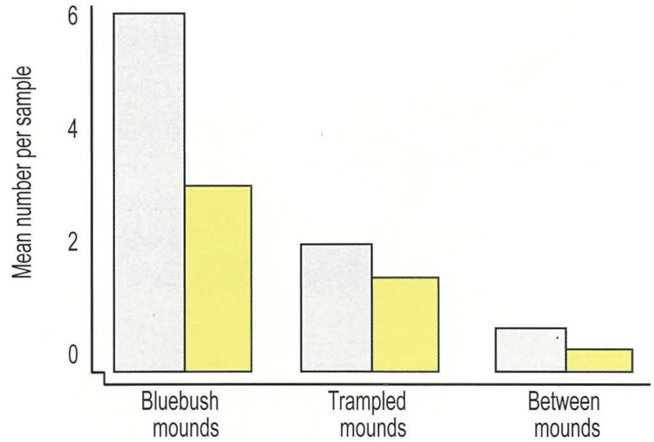
Around each bluebush, mounds of soil trap organic matter and other nutrient resources. These 'fertile patches' in this nutrient-poor ecosystem are important to the maintenance of ecological productivity. The mounds are important faunal 'hotspots' and biodiversity reservoirs, where the mite fauna is many times more diverse and abundant than in the surrounding soil. In these kinds of dryland ecosystems, soil mites are the dominant animals and are important contributors to the decomposition of soil organic matter and the maintenance of soil structure.

What happens to these reservoirs of biodiversity when the landscape is degraded by overgrazing?

When sheep graze the bluebush, they can cause degradation of the bluebush mounds due to their hard hooves and their tendency to walk through, rather than around, the bushes as they feed (not too unexpected for sheep!). If the grazing is too heavy the blue bush may die, and the exposed mounds gradually degrade and disperse, losing their 'fertile patch' properties. As the mounds break down, the mite diversity and abundance declines, until finally, the communities are little different from bare, exposed soil.

The soil mites most affected are the small, fragile fungal grazers (the groups which are known to accelerate plant decomposition), many of which disappear altogether from soil samples. Losing the bush cover over the mounds is the most important step and is when the greatest biodiversity loss occurs. Heavier grazing by itself, without bush loss, produces much smaller declines in biodiversity.

The loss of the fertile and biodiverse patches by inappropriate landuse is central to the landscape degradation story in these rangelands and in others throughout Australia. The good news for the rangelands is that there seems to be a healthy degree of resilience in this ecosystem. That is, when the disturbance (in this case overgazing) is halted and the landscape allowed to recover, the mite communities, even in the most degraded areas, begin to recover inside the degraded mounds within a year.



□ Number of animals per sample
■ Number of species per sample

CASE STUDY

How Many Insects?

Harry Recher

One of the most fascinating questions asked by biologists is "how many different kinds of animals are there?" Mostly, this is expressed as "how many species are there?", but we could just as well say "how many insects?" Of all the different kinds of animals and plants on Earth, on the land and in the sea, insects are the most 'biodiverse'. That is, there are more different species of insects than there are of all other organisms combined. Among the insects, the group with the greatest number of species are the beetles or *Coleoptera*.

Photograph courtesy of the late George Lowe

Harry Recher, Professor of Environmental Management at Edith Cowan University and Jonathan Majer, Professor of Environmental Biology at Curtin University have been asking "how many kinds of insects can you find on a single eucalypt tree?" At first, they used cherry-pickers and chemical fogging machines to collect insects from the tops or canopies of trees as high as 21 m above the ground. More recently, they have been trapping insects on the trunks of trees only 2 m above ground level. What they have found changes the way we think about biodiversity in Australia.

From the canopies of just four species of eucalypts, jarrah and marri from the west and grey box and narrow-leafed ironbark from the east, they collected nearly 2000 species of insects and spiders; more kinds than there are species of frogs, reptiles, birds and mammals on the entire Australian continent. From the bark of jarrah, marri, wandoo and powderbark wandoo trees along a transect following the Brookton Highway to Brookton and then cutting across to Dryandra near Narrogin, nearly another 2000 species of insects and spiders have been identified. Some of these would be the same as found in the canopy, but the numbers begin to show just how rich Australia's evergreen eucalypt forests really are.

By the way, only a few of the species sampled in these studies have been formally described by science and so Professors Recher and Majer refer to them as 'morphospecies' and give them numbers. One day, each morphospecies will be given a formal scientific name and lodged in a museum (the Western Australian Museum for specimens collected in the west and the Australian Museum for specimens collected in the east). This way other scientists will be able to compare the insects and spiders they may collect to those already sampled and named.

The work done by Harry Recher and Jonathan Majer is typical of many studies done at Australian universities where scientists with different backgrounds work together on a project. Professor Recher is an ecologist with special interests in birds, while Professor Majer is an ecologist with special interests in insects, especially ants. Birds eat insects so working together made a great deal of sense. Part of their joint studies is an investigation of just how do birds respond to insects and how are insects affected by birds.

After 16 years of collaboration, Professors Recher and Majer can tell us that insect-eating birds choose to feed in different kinds of trees according to the kinds and numbers of insects on each kind of tree. Bark-foraging birds particularly select large trees and trees with an abundance of bark insects and spiders. Knowing this is important for managing forest wildlife - big trees are important as feeding places for many birds. By putting bird mesh around sapling eucalypts and stopping birds from feeding on insects and spiders, Professors Recher and Majer found that not only did the number of insects and spiders increase when the birds couldn't eat them, but there were more big insects and spiders and more insect damage to the eucalypts' leaves. Maybe this doesn't surprise you, but it shows how important having birds around might be for forest production. They can also tell you that a big, old eucalypt standing in the middle of a sheep paddock has an amazingly rich insect fauna and that even single trees and small patches of remnant native vegetation are important for the conservation of Australia's biodiversity.

This may not sound like much for 16 years work, but the applications of their studies are just beginning. For example, many Australian farmers are now re-planting trees on their land to control rising groundwater and salinity, and to encourage wildlife. In a study near Northam, Professors Recher and Majer were able to show that planting trees already found in the area (indigenous trees) is much better for encouraging wildlife than planting similar trees from even short distances away (non-indigenous). Indigenous trees not only had more kinds of insects, they had greater numbers, meaning more food for birds and other insect-eating animals. The exotic trees, those from the eastern states of Australia or overseas, planted on Perth's streets and gardens have even fewer kinds of insects and spiders and do little to encourage urban wildlife.

Working with people from other universities or from different areas of study (disciplines) within a university is one of the great rewards of education, study and research. Students in the School of Natural Sciences at Edith Cowan University are encouraged to attend meetings and to exchanges ideas with students at other universities. In this way, life long partnerships develop which are important for the advancement of science and for the conservation of our native wildlife.

Postscript: How many insect species are found in Australia? Well, officially only 250,000, but Professors Recher and Majer are certain there are more than 1 million.

Diversity in the Mulga and Spinifex Country

Eddie van Etten

Get in a car and drive north of Perth; in three to four hours you will find yourself in fairly flat and featureless country dominated by mulga (*Acacia aneura*), a ubiquitous small tree or shrub across much of arid and semi-arid Australia. This landscape continues for hundreds of kilometres in all directions. Continue further north, past the Tropic of Capricorn, and spinifex grasses (of the genus *Triodia*) take over and cover the hills and sand dunes as far as the eye can see. Mulga and spinifex vegetation cover some three-quarters of Western Australia and the view from the window will probably convince you they contain few species of plants. Indeed, the common public perception of these lands has been that they are species-poor deserts with little value for biodiversity conservation.

View from the top of Mt. Bruce looking south-east over the Hamersley Ranges landscape in the Pilbara. The landscape is well sorted into distinct landforms and vegetation types. Species diversity varies widely from type to type, most likely in response to fine-scale variation in environmental features.

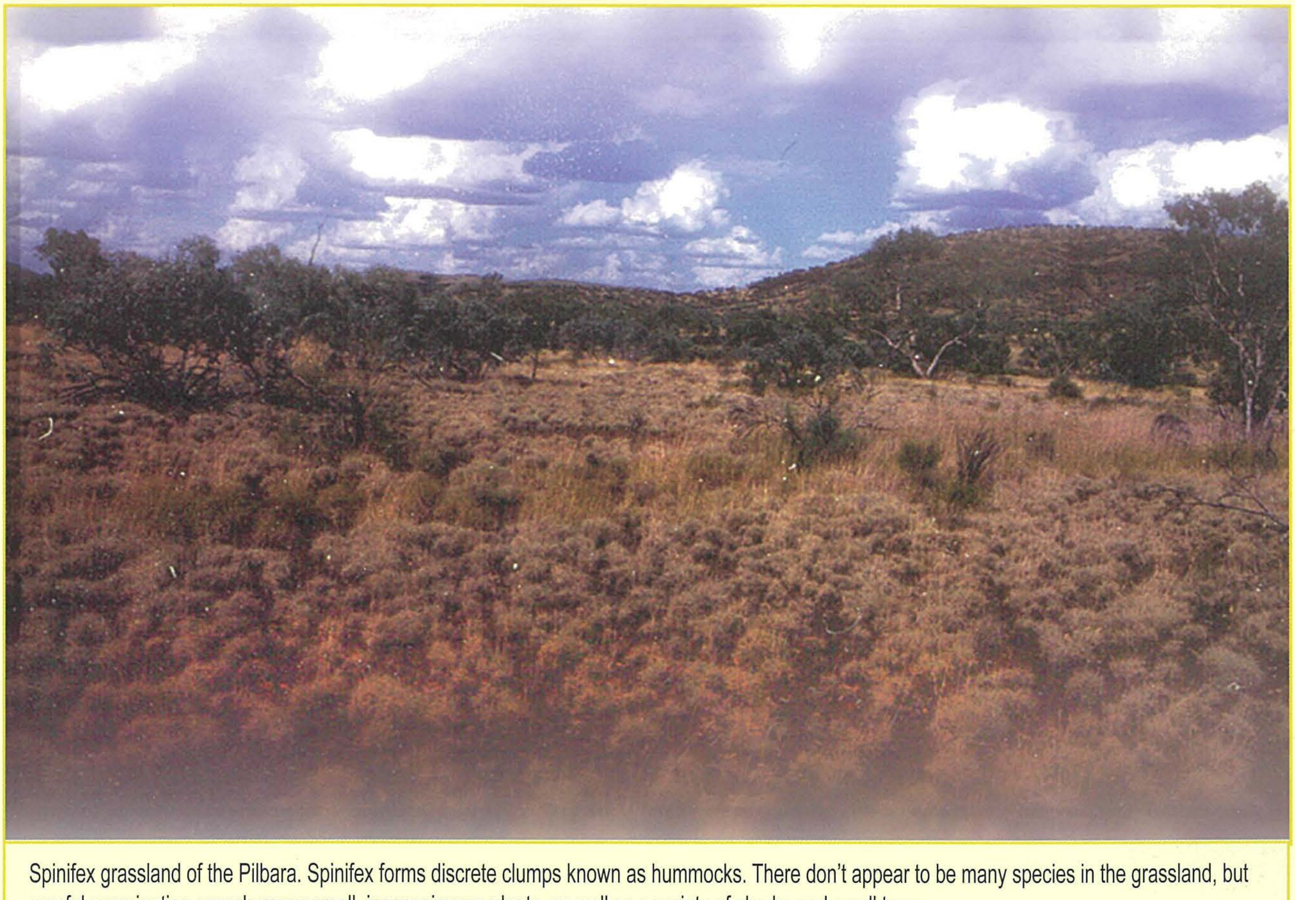
Get out of the car, walk off the road a bit, mark out an area of, say, 20 by 20 metres, count the number of different plant species inside this 'plot', and you could be in for a surprise. This is what Dr Eddie van Etten and assistants from ECU's School of Natural Sciences did over a number of field trips to the Pilbara region during the 1990s. The number of plant species they found was quite astounding. The highest number in one of their plots was 70, with the average number close to 30. These numbers are actually similar to those found in other arid lands with comparable rainfall averages. Most of the plots were dominated by only one or two species, so the perception, particularly when viewed from a car, is understandable.

The counting of plant species in the Pilbara was not done just for the purposes of comparison.

Spinifex grassland in the Pilbara a few months after heavy autumn rainfall. Note the large number of ephemeral species such as mulla-mullas, daisies and goodenias

It was part of a large research project trying to better understand the patterns of plant species across such a landscape. Most of the variation in the number of plant species was attributable to the amount of rainfall in the months before sampling. If the area had received ample rain, many ephemeral species, such as everlastings, annual grasses, mulla-mullas, native cornflowers and goodenias, carpeted the ground. If the summer cyclonic deluges and winter rains didn't arrive that year, none of these short-lived species were found. Somewhat unexpectedly, the number of long-lived, perennial species was also strongly linked to rainfall. This is due to enhanced seeding and germination during 'good' years, and increased plant death during drought years. Ignoring the effect of rainfall, quite profound differences in the number of plant species were found from place to place. Some plant communities were species rich (such as creeklines, hill-tops and mulga woodland communities in broad valley systems), while others had few species (such as spinifex grasslands on pediment slopes at the foot of mountains and hills). The underlying causes of this variation cannot be easily confirmed, but the positive correlation between the number of species and variables such as rockiness, soil depth and plant density favour a niche theory explanation. That is, the greater the variation in environmental conditions within a site, the greater the number of potential niches, and the more species will be found per site. Rocky sites, such as areas with outcropping of parent rock, vary considerably in terms of soil conditions - between the cracks and rocks, soils are fairly deep and retain moisture for long periods, whereas elsewhere soils are shallow and dry quickly. Fine-scale variation in shade and microclimate would be expected to be high at sites with dense tree cover.

Just as important as the number of species co-occurring at a site is how the species present change from one site to another. In other words, what is the turnover of species as one moves through the landscape? This was found to be relatively high in the hilly and mountainous terrain of the Pilbara reflecting the fact that several distinct landforms and soil types occur in this well-sorted, stable landscape. Moving down the slope of a hill and through a broad valley system, there is a gradual turnover of species, but this is particularly high across the transition from hill slopes to stony pediments, and from these pediments to the fine soils on flats. Pilbara landscapes can therefore contain many hundreds of species due to the fact that individual sites may harbour many species and high turnover often occurs from site to site. Altogether, the Pilbara region contains an estimated 2,000 species, 10% of which are believed to be found nowhere else. Although the study has given us insights into what might be controlling species numbers and composition in the Pilbara, the undeniable message is that we should appreciate that areas outside the State's south-west, an area renowned for its floral diversity, may also be reasonably rich in plant species.



Spinifex grassland of the Pilbara. Spinifex forms discrete clumps known as hummocks. There don't appear to be many species in the grassland, but careful examination reveals many small, inconspicuous plants, as well as a variety of shrubs and small trees.

Photograph courtesy of Rob Drummond

Conservation Biology

Harry Recher

Conserving and managing biodiversity is the science of 'conservation biology'. Conservation biology is a major interest of staff and students in the Environmental Management and Biology programs at Edith Cowan University. Conserving and managing biodiversity are the reason many of us took up careers in the sciences. A career in biological conservation provides opportunities to work almost any place one chooses - at least, any place where there are plants and animals. At ECU, we have research programs on Antarctic islands, in the Kimberleys of Western Australia and the Everglades of southern Florida in the United States, as well as the marine studies described in another section. Students work with plants, birds, mammals, fish and invertebrates in woodlands, wetlands, deserts and rainforests throughout Western Australia. Some studies are of communities, such as the birds of eucalypt woodlands, while others fix on individual species. Among the species studied at ECU are the Western Yellow Robin at Dryandra near Narrogin, the Dibbler on islands off the Western Australian coast at Jurien, and ravens (crows) in Perth. Biological conservation is about more than species conservation. Conservation biologists at ECU want to know how land clearing and habitat fragmentation affects the flora and fauna and what makes old growth forests special. But it is not enough just to acquire knowledge about our native wildlife, we need to know how to apply that knowledge for conservation and management. What makes land owners protect the biodiversity on their farms? How do you use genetics to manage or restore rare and endangered species? What is the role of disease in species conservation? These are research questions asked every day by staff and students at Edith Cowan University. Answering them is an important part of the education process, as is communicating the answers to government, industry and the community. In this way, environmental management students can not only satisfy their curiosity about the natural world, but they can have a real impact on making the world and Western Australia a better place in which to live.

Dugongs: graceful cows of the sea

David Holley, Darren Capewell and Paul Lavery

The dugong (*Dugong dugon*) is a marine mammal found in the tropical and subtropical regions, from eastern Africa to Vanuatu. It is also known as the 'sea cow' as it is a herbivore that spends most of its time grazing on seagrasses. Anyone who has experienced the pleasure of snorkeling with a dugong will know that the name does little justice to the grace of these animals underwater. The dugong is found throughout northern Australia. The Shark Bay Marine Park World Heritage Property in Western Australia is home to one of the largest and healthiest populations of dugongs in the world, a population supported by the extensive seagrass meadows that occur throughout the Bay. Dugongs feed on at least five of the 12 seagrass species that grow within Shark Bay. Dugongs inhabit almost the entire Bay but move to different regions at different times of the year. The movement patterns of the dugongs appear to be driven mainly by their search for warm waters. During winter they move to the upper west of the bay, near the warmer ocean currents. In summer, they are found to the east of the bay in the lower reaches of the bay, where the waters are shallow and warm. Scientists at ECU are collaborating with researchers from the Department of Conservation and Land Management, James Cook University and members of the local aboriginal community, the Yadgalah Aboriginal Corporation (Inc.), to

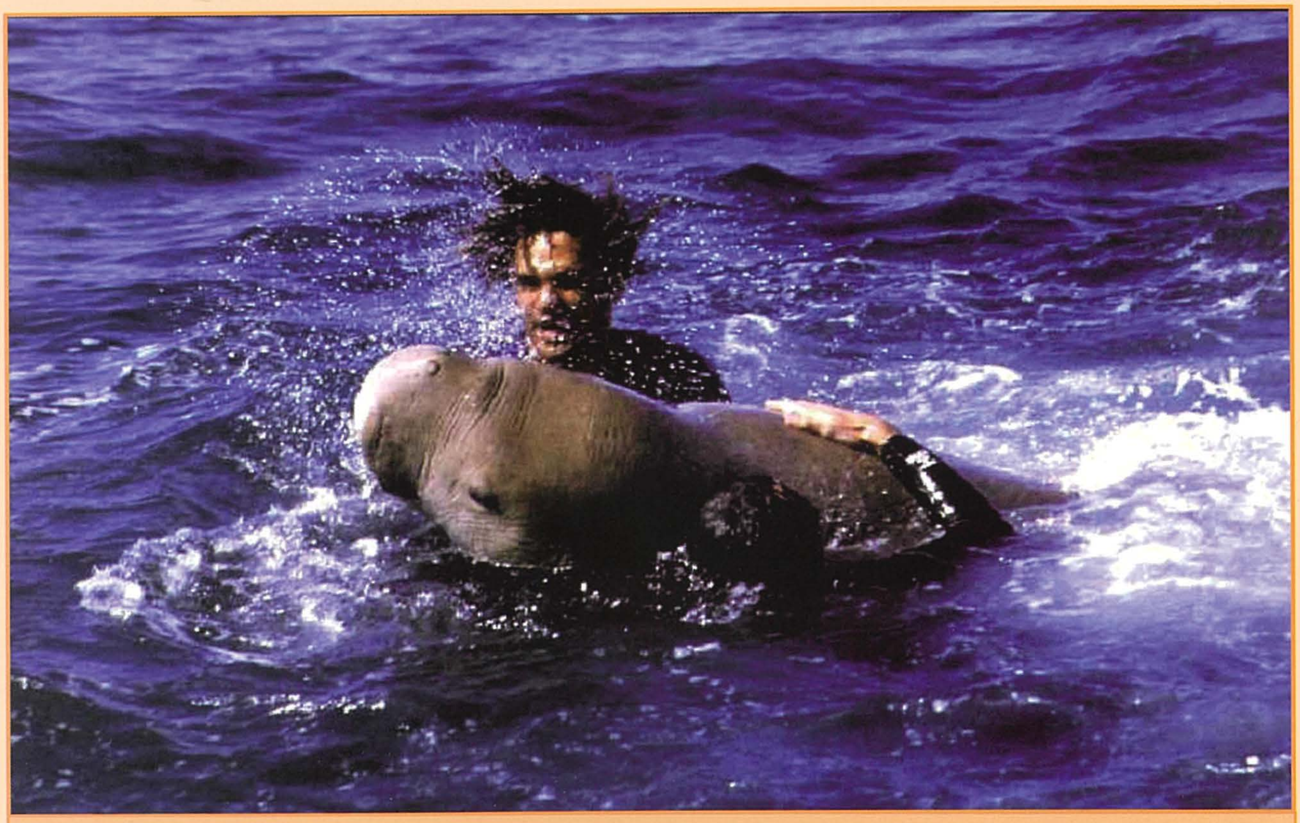
A harness is fastened around the peduncle of a dugong

The tagged animal is released and swims away towing the satellite GPS tag (in catcher's hand)

better understand these movement patterns and the importance of seagrasses for dugongs. The project aims to identify areas within Shark Bay that are important to dugongs and what makes them important. For example, is an area an important feeding ground and, if so, which species of seagrass grow there? Should these areas be considered - and perhaps specially protected - as important refuges for dugong conservation? It is only by answering these questions that environmental mangers can plan adequate protection strategies for the dugong. From the Yadgalah's perspective it may also provide the information needed to ensure that they can

Seagrass (*Amphibolis antarctica*) meadow in Shark Bay — a major feeding habitat for the Dugong continue to practice the tradition of hunting animals in a sustainable manner. Our earlier understanding of movement patterns was based on direct observations by researchers, who would either follow dugongs in a boat or map them from a plane. The latest research has taken advantage of sophisticated satellite-tracking technology to follow the movement of individual dugongs. The state-of-the-art Geographical Positioning System (GPS) tags being used in this research can record a dugong's position to within 10.5 metres of its true position. As the dugongs move around

Photograph courtesy of Dan Costa



Dugong catchers supporting a Dugong prior to tagging

Shark Bay, their positions are electronically recorded. Later, the tags and the valuable data they contain are retrieved and the information used to construct maps of dugong movement. An important first step in the research was learning how to catch animals, attach the tags and then release the animals without placing unnecessary stress on them. Members of Yadgalah are vital to the dugong capture operation. They are the chief catchers and spotters, locating suitable animals and then guiding the boat driver, during what can be a fast and exciting chase. When the boat is close enough to the dugong, the catcher leaps off the boat and holds the dugong around the peduncle - a narrow area just ahead of the tail. Others catchers then enter the water and restrain and support the dugong so that it does not hurt itself and can breathe freely. A foam 'noodle' is used to cradle the dugong's pectoral fins until the tag is attached. Once this has been completed, the animal is released, towing the tag behind it. Twenty tags have been deployed on dugongs within Shark Bay and are beginning to provide us with a clearer picture of the movement and habitat use of dugongs. This information will allow managers, including the traditional owners, to make more informed decisions regarding the impact that human activities within the marine park may have on the dugong and its habitat.

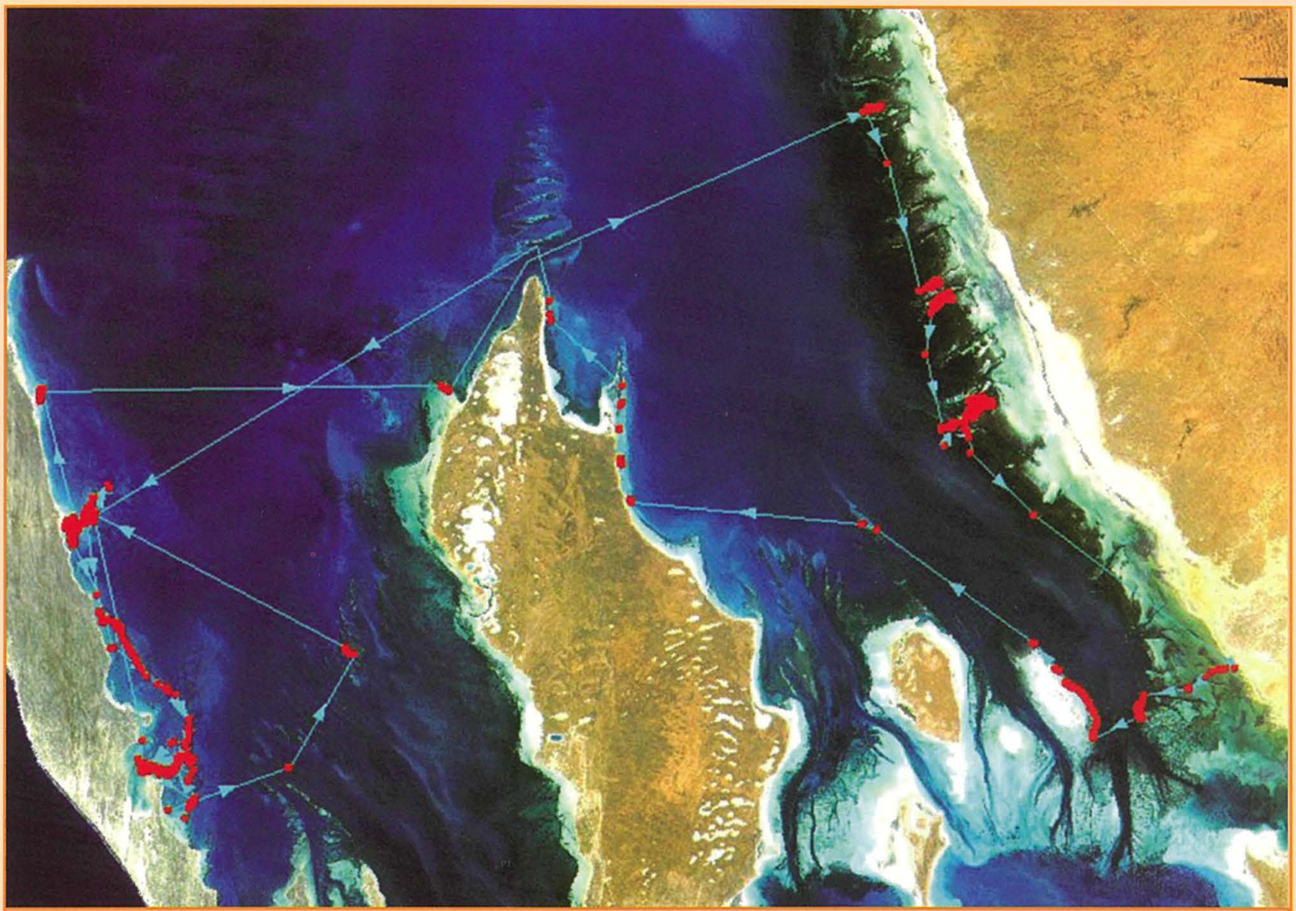


Figure 1
The movement pattern of one dugong in Shark Bay. The red dots indicate locations where the GPS tag recorded the animal's position, and the lines show the path the animal took in moving around the bay.

Strengthening Nature Conservation on Private Lands

Thomas Kabii

In recent times, nature conservation on private lands has gained greater attention at national and global levels with the growing awareness that they hold a significant number of rare and endangered species that are not well represented in our national parks and reserve system. Despite this growth in awareness and the existence of regulations to protect biological diversity on private lands, degradation and significant loss of biodiversity continues as a result of clearing of land for agriculture, development or infrastructure.

Inadequacy of the conventional 'command and control' mechanisms such as regulations to protect biodiversity on private lands has led to a search for more effective mechanisms. Some of these include management agreements and covenants in perpetuity, which have already been in use in the United States, in parts of Europe, and more recently in Australia.

Voluntary management agreements and covenants are defined as written undertakings between a landowner and another party such as the National Trust of Australia or CALM, in which the landowner voluntarily agrees to retain and maintain significantly important nature conservation areas on the property in return for support such as management advice and some funding to help in the management of the conservation areas that are placed under the agreement. The difference between a management agreement and a covenant is that a covenant is attached to the property title and is therefore legally binding on the present and future owners of the land while a management agreement is not attached to the land title and therefore only affects the current owner of the land. In Australia, covenants in particular, have received more attention lately because of their seemingly greater ability to ensure long term nature conservation on private lands than other mechanisms. Despite the view of covenants as a viable mechanism for nature conservation, many landowners have been reluctant to adopt them. The reasons for this have not been comprehensively investigated or understood. It is clear, however, that lack of information on the covenant mechanism and lack of understanding of the factors that influence the decisions of landowners lead to the design and implementation of inappropriate covenant mechanisms and programs. This is particularly evident in countries with limited experience in their use.

In principle, nature conservation on private lands is for the good of the community but is dependent on the motivation of the individual landowners. Motivation is in turn a function of several interactive factors that include; landowners' perceptions and attitudes to covenant mechanisms, nature conservation values, moral obligations for conservation, the level of incentives available, landowners' assessment of the present and future utilitarian value of the land, and willingness of government/others to pay compensation. These issues and their influence on conservation decisions need to be comprehensively investigated and understood before effective covenant mechanisms can be developed.

A comprehensive investigation of the factors and issues that influence private landowners' decisions towards the voluntary uptake of a covenant was carried out between 1998 and 2002. The study was based on a questionnaire mail survey sent to randomly selected landowners in Victoria and Western Australia. One of the aims of the study was to investigate if there were significant differences in the factors that influence the decisions of landowners to take up a covenant for nature conservation between Victoria and WA, since Victoria has wider usage of conservation covenants than WA.

The questionnaire included several questions relating to landowners' perceptions of covenants as conservation mechanisms, their socio-economic characteristics, their long-term goals for the property in relation to retention of management and ownership, the characteristics of the land, their views regarding conservation and how they regarded the issue of incentives. The purpose of all these questions was to establish if there were significant correlations between the factors identified above and the landowners' likelihood of taking up a covenant.

The findings of the study were aimed at providing better information to aid in the formulation of conservation policies and strategies on private lands in Australia. Studies of this nature, that investigate the human interface with the environment (in this case nature conservation), are receiving increased attention from the conservation movement and from policy makers. This is because there is a growing recognition of the need to understand human behaviour as it impacts on the environment and how this behaviour can be moulded towards a positive outcome for the environment. The recognition that humans are an integral component of ecosystem functions has also led to closer examination of their role and how they can be influenced to achieve desirable outcomes.

A Crested Shrike-tit

Photograph courtesy of Michael Morcombe

Morning Song

Gary Luck

What is the first thing you hear when you wake up in the morning? Is it the hum of traffic on a nearby road? The sound of your family making breakfast? Dogs barking? If you have a garden with trees or shrubs, or live near a park, one of the first things you probably hear is the morning song of the resident birds. One of the greatest pleasures of camping outdoors is to awake to the dawn chorus of birds. Each choir member has a different song, but all fit together to form a melodious symphony that celebrates the sunrise. Have you ever wondered what it would be like without these songs?

In the agricultural region of southwestern Australia, the songs of numerous birds that were once common are heard no longer. The islands of remnant native vegetation that dot the wheatbelt of Western Australia are not sufficient to support all bird species. Many islands have lost the most harmonious part of their treasure. Birds that have declined in abundance include the Crested Shrike-tit and Rufous Treecreeper. These particular species commonly use open woodland habitat. This habitat was cleared for farming because it was associated with the most fertile soils. Only a small percentage of woodland remains and woodland bird species have few places in the wheatbelt to call home.

Woodland patches provide birds with food, shelter and nesting sites. Food is obtained from the branches and leaves of trees, flowers and from the ground. It includes nectar, seeds and insects. Shelter is provided by shrubs, the canopy of trees, or hollows in branches and tree trunks. Many birds also build their nests inside hollows because this provides protection from predators, rain and wind. Clearing woodland means less food, less shelter and fewer nest sites for birds. Some birds are able to cope with living in small or degraded patches of woodland, but most can not. These are the species whose morning song has not been heard for many years.

It is not all bad news. Many of the birds that have been lost from the agricultural region of southwestern Australia still occur in National Parks and nature reserves. However, these areas are not large enough to ensure that all species will continue to survive into the future. If we can improve the woodland habitat in agricultural districts so that it is again suitable for most birds, we may see the return of many species to these landscapes. Once again, these birds would join the morning chorus to herald the dawn.

Management: does the future lie in the past?

Photograph courtesy of the Australian Museum

Chris Norwood

Australia's landscape is ancient. It has incorporated human beings for between 40 and 60 thousand years. Prior to the arrival of European colonists in 1788 environmental change had been very slow. Since that date extensive and sometimes rapid changes have taken place in the landscape of the continent. The diversity and prevalence of native flora and fauna has in most cases diminished significantly. We are now faced with the question of how best to manage remaining resources to ensure their survival for future generations.

In pre-European settlement times the indigenous population managed the environment effectively, with little impact, after the original colonisation and dingo, on the natural balance. Their environmental management was not a discrete discipline. Rather it was embodied in their religious and cultural practices and traditions. However, the alienation of people from their traditional land and the practice of their cultural obligations have excluded indigenous people from participation in activities that in former times contributed to the maintenance of a healthy ecosystem. Furthermore, this loss of traditional structures and of ongoing contact with the land has contributed to a loss and degradation of knowledge.

Europeans introduced intensive farming, mining, and manufacturing activities, accompanied by permanent sedentary settlements. The focus of economic activity is on the exploitation of nature to generate wealth, with minimal value being accorded to the preservation of the natural environment because of any perceived intrinsic worth. As global economics gains increasing domination of domestic activities, the pressures to be more recklessly exploitative increase. This generates problems and pressures on the land which are more extensive and destructive than those which were addressed by the first Australians.

Modern scientific studies are struggling to find solutions to ameliorate the environmental impact of our postindustrial society. The knowledge held by indigenous Australians may provide an important key in the development of new solutions. Unfortunately traditional knowledge in isolation is unlikely to solve many of the current problems, which are products of today's social structure, increased population, and a very different relationship with nature. There will be challenges to overcome in attempts to integrate elements of divergent cultures into a unified approach to find solutions.

More successful land claims by traditional landowners will lead to indigenous people regaining custodianship of their traditional lands. With the resumed responsibilities associated with custodianship we can hope to see young indigenous Australians educated in scientific management and able to merge it with traditional knowledge to provide a future for all Australians. The future health of the environment will depend on the application of present and future scientific knowledge in conjunction with knowledge held by this country's first conservationists, the indigenous people of Australia.

Attributes of Old Growth Forest

Alexander Watson

Forests cover almost 40% of Earth's land surface, and are distributed on all continents except Antarctica. As different forests have distinct geological, climatic and evolutionary history, they are all repositories of biodiversity. 'Biodiversity' encapsulates all life forms, the ecological roles they perform, and the genetic diversity they contain. Natural forests are extremely important to human welfare. Each forest consists of thousands of species which together produce clean air and water, cycle nutrients and naturally protect against the 'greenhouse effect' by storing carbon. The most readily accessible resource provided by forests is timber and pulp.

Through logging, humans have had a profound impact on many forests. The damage created by logging is mostly unknown because 99% of species found within natural forests are not described. These include the fungi, bacteria, arthropods and non-vascular plants now recognised as the major predators, herbivores, symbionts and decomposers that together drive forest ecosystems.

HUMAN IMPACT ON AUSTRALIAN FORESTS

Australia has many different types of forest distributed in moderate to high rainfall zones. They range from monsoon rainforests which are thinly scattered in the escarpments of northern Australia to cool temperate rainforest found on the mountaintops of Tasmania and eastern Australia. Wet and dry sclerophyll (Eucalyptus) forests dominate the east and southwest of the continent.

Prior to European settlement, Aboriginal communities used forests extensively. These ecosystems were important areas in which food, firewood and other materials were gathered. Fire was used extensively, primarily to manipulate vegetation to facilitate hunting and encourage native mammals. It is speculated

Photograph courtesy of Jiri Lochman/Lochman Transparencies that Aboriginal communities modified many Australian environments through their regular use of fire. For example, regular burning, in conjunction with climatic changes, may have caused rainforest contraction over the last 40 000 years on this continent. This is because many rainforest species are intolerant of fire.

European settlement has had an enormous impact on Australia's forest. Almost half of Australia's forests have been replaced for agriculture, roads, housing and other uses in the last 200 years. The majority of the remaining forest has been used for production of lumber and, more recently, pulp (woodchips). Only a small proportion of the original forest cover is undisturbed 'old growth' forest.

Recent management of the Australian forests has been characterised by conflict. Conservationists contend that regular logging and burning seriously degrades forests' integrity, and predict if current practices are maintained, major losses of biodiversity will occur. Forest managers argue that logging is compatible with conservation provided that sufficient areas are reserved and that appropriate measures are taken within production forests to mitigate the effects of logging. It is apparent that unless this conflict is resolved, Australia will lose important opportunities for investment, local communities will continue to be plagued by division, and species may become extinct.

UNDERSTANDING HOW FORESTRY AFFECTS NATIVE FORESTS

Understanding how modern forestry affects native forests can only be achieved after the characteristics of undisturbed forest are recognised. This is problematic as there are thousands of undescribed species in each of Australia's forest ecosystems. The only way to attempt to assess the impact of this disturbance is to use one or a group of 'indicator' species. These organisms should be representative of the primary, secondary and tertiary consumers of the forest which they inhabit, as well as have life history characteristics that rely on attributes of old-growth forest. Table 1 outlines some of the primary characteristics of old-growth Eucalyptus forests, and some of the organisms that are thought to rely on these characteristics. These organisms can be used as 'indicators' of old-growth characteristics, and be subsequently used to measure the impact of logging and other forms of disturbance.

Research conducted at Edith Cowan University is currently using this approach to understand the impact of forestry in jarrah forests near Perth. It aims to assess whether jarrah forest recovers the attributes and associated organisms (including birds, litter arthropods, bark invertebrates, understorey shrubs, log dependent arthropods) of undisturbed forest after logging.

Old-growth Eucalyptus forest attributes	Organisms that have life history traits that are related to attribute
Large, old trees	Bark dwelling invertebrates including beetles, bugs and spiders. Birds and mammals that require large hollows to breed (e.g. cockatoos, possums) or large trees to forage (e.g. sittllas)
Large crowns interspersed with large gaps	Understory plant species that require particular light regimes and soil moisture conditions (e.g. ferns, orchids)
Large, old logs	Log dwelling invertebrates including termites, slaters, spiders and beetles Fungi and moss
Relatively undisturbed deep litter levels	Exotic plant and bird species Leaf litter invertebrates including ants, spiders and beetles
Nutrient cycles in dynamic equilibrium	Soil and leaf bacteria and fungi

Table 1
Some structural, compositional and functional attributes of old growth Eucalyptus forests, and organisms that depend on these attributes.

The Need for New Environmental Politics for Native Forests

Martin Brueckner

Over the last 15 years public sentiment has changed dramatically regarding environmental issues. While in the past the voicing of environmental concerns was perceived to be limited to so-called 'alarmist scientists', 'pot-smoking hippies', and 'tree-hugging ferals', the last decade has witnessed a surge in widespread public awareness of and concern for the natural environment. This phenomenon was apparent in Australia during the Regional Forest Agreement (RFA) process in the late 1990s when unprecedented numbers of the general public became involved in voicing their concerns about the future of Australia's native forests.

The debates surrounding environmental issues have traditionally been focussed on the incompatibility of economics and environmental protection. We all have come across catchphrases such as 'Jobs versus Trees', highlighting the conventional perception that environmental protection and conservation are costly and hence economically undesirable. In recent years, however, the focus of these debates has been widened to include insights from scientific fields such as ecology and sociology as well as drawing on indigenous knowledge and human sentiments such as emotions and spirituality. This shift is indicative of a growing awareness that environmental issues cannot be dealt with exclusively using hard science and economic rationalism but require a holistic problem solving approach.

These changes in public perception and changes in the nature of the environmental debate have serious implications for political decision makers and democracy at large. While in the past political decision-making occurred behind closed doors, relying generally on society's apathy towards environmental issues, today calls are being made for more transparent, inclusive, and participatory government processes. The RFA process was one of the first attempts in this country in which government worked jointly with members of the general public, conservation groups, and forest industries towards a solution for a 25 year old dispute in relation to forest use and protection. In essence, what was attempted was a bringing together of government, members of the general public (households) and industry (business), trying to decide on pathways, rules, and regulations for a sustainable future for Australia's forests and forest-dependent industries.

Currently, research is being undertaken at the Centre for Ecosystem Management, Edith Cowan University, looking at the Western Australian RFA process, which was formally concluded in May 1999. It is the aim of this research project to analyse the WA RFA process itself and the outcomes achieved in view of its scientific, democratic, and participatory nature. Employing a theoretical framework based on social ecology, analysis is being made of RFA stakeholders' perceptions of the strengths and weaknesses of the RFA process. Comparisons will also be made between the Western Australian RFA and other RFAs signed around the country to assess their differences in approach and outcomes. It is the intention of this study to identify the lessons that can be learned from a government process such as this and to aid environmental policy design and political decision-making processes in the future.

Although the core focus of the Centre for Ecosystem Management is directed at what is generally referred to as 'hard science', work in the more qualitative, sociological field of science can be of value to the Centre and environmental management at large. This is because interdisciplinary approaches widen the focus of individual disciplines and enable collaboration between scientific fields commonly thought to be unrelated. Furthermore, in view of growing environmental pressures and resultant difficulties for environmental resource management and governance, holistic research methods may prove to be useful in dealing with the increasing complexities in environmental issues.

The Australian Raven: *Corvus coronoides*

Suzanne Cumming

The Australian raven is a member of the genus *Corvus*, which contains 106 members worldwide. Within Australia, the genus consists of two species of crow - the Torresian crow (*C. orru*) and the Little crow (*C. bennetti*), and three species of raven - the Little raven (*C. mellori*), the Forest raven (*C. tasmanicus*) and the Australian raven (*C. coronoides*).

The distribution of the Australian raven extends throughout rural and urban southern and eastern Australia and, in rural areas, closely parallels that of the sheep farming regions. Carrion is one component of the omnivorous raven's widely varying diet which also includes insects, and plant matter such as seeds and fruit. Urban environments provide a reliable food source for omnivorous birds. Plant matter, invertebrates and small animals can be obtained, plus there are human-created resources such as rubbish bins and dumps, general roadside and park litter, and bird feeders.

Mature raven pairs occupy territories within which they are resident the year round. All foraging occurs within the boundaries of their territories which they defend against intruders. Nests are built high in the tallest available trees to enable a full view of the territory, and may be used more than once. Young ravens leave their parents at six months and join nomadic flocks which wander over wide areas. Ravens do not reach maturity and breed until their third year, in which they leave the nomadic life and settle down on a territory of their own.

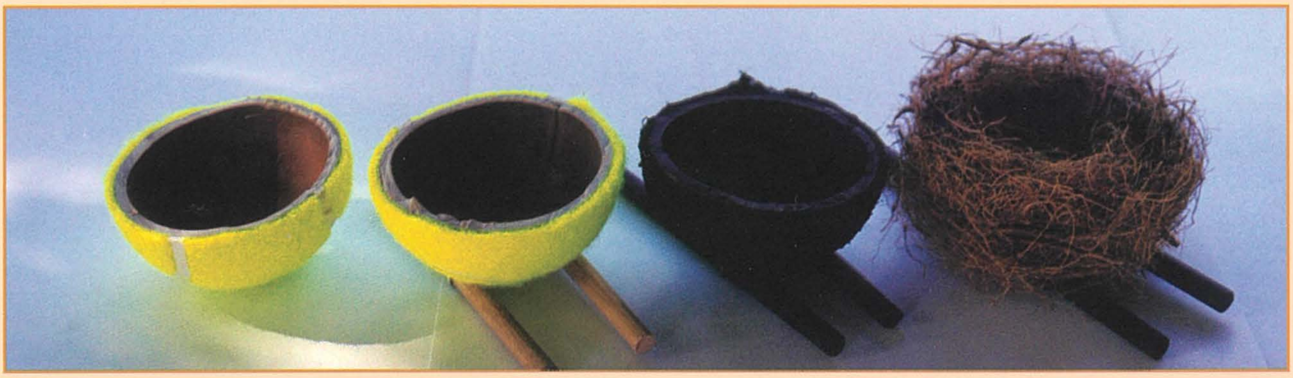
Although ravens occur in a range of habitat types, they prefer to reside in open country with scatterings of tall trees, such as woodland, natural or artificial parkland, forest edges, and cultivated areas.

These features have pre-adapted ravens to many of the types of habitats created by humans, such as agricultural and urban landscapes. Over the past 30 years, clearing of extensive areas of native vegetation has increased the area of habitat suitable for the raven, and has seen its distribution and abundance expand. Furthermore, their intelligence and ability to learn have enabled them to thrive. This expansion has seen the Australian raven become the dominant *Corvus* species in Canberra, Sydney, Melbourne (with *C. mellori*) and Perth.

The Australian raven has also increased in abundance since the reduction in its persecution and control by humans. This occurred after they were found to be beneficial rather than detrimental to sheep farming.

A recent study on the Australian raven in Perth's southern suburbs, conducted through the Centre for Ecosystem Management at Edith Cowan University, revealed that the raven population is unevenly distributed. Raven abundance is higher along main roads and in close proximity to major shopping centres and water bodies. Raven abundance is also higher during the non-reproductive season when the previous season's juveniles have reached independence and formed or joined nomadic flocks.

Surveys conducted throughout 2000-2001 estimate raven density to be 16 ravens per square kilometre during the reproductive season and 22 ravens per square kilometre during the non-reproductive season. These figures are likely to be overestimations because many transect lines are along main roads due to the difficult nature of conducting surveys in an urban environment.



Diseases of House Mice on Sub Antarctic Macquarie Island

Dorian Moro

HUMAN IMPACTS IN THE ANTARCTIC

Macquarie Island is wild and rich in beauty. Like other sub Antarctic islands, these places are important land masses for a large percentage of marine birds and mammals of the southern hemisphere. Yet their exploitation by sealers to support an oil and sealskin industry in the 1800s led to an invasion of exotic species, including rats and mice. With these invasive species came diseases that the local fauna had not been exposed to before.

Understanding which diseases (virus, parasite or bacteria) this species carries can help us to understand the role mice have in the transmission of diseases there, especially as the sub Antarctic fauna remains so isolated and may not have previously been exposed to a particular disease agent brought in by an invasive species.

Prior to their eradication, House Mice were abundant on sub Antarctic Enderby Island. Explanations of a mass mortality of New Zealand Sea Lions on Enderby Island in 1998 remain unknown, although Salmonella bacteria have been implicated. Were these bacteria exotic to the island, or part of the native population there?

DISEASE IN WILDLIFE

Knowledge of infectious and parasitic diseases among island exotic fauna is meagre and fragmentary. The introduction of rodents to islands can impact upon these environments. House Mice are well-known carriers of disease.

MACQUARIE ISLAND

Sub Antarctic Macquarie Island lies mid-way between Australia and Antarctica. It is an important island habitat to thousands of Elephant Seals and to four species of penguin (Royal, King, Rockhopper, Gentoo), in addition to several species of Albatross. However, Macquarie Island is also inhabited by House Mice and Black Rats brought in with cargo by sealers during the 1800s.

A collaborative project between Edith Cowan University and The University of Western Australia, and with support from the Australian Antarctic Division and Australian Geographic, seeks to investigate the occurrence of mouse viruses and parasites present in this island population, compare it to those found in other populations of House Mice in Australia, and learn about the persistence of viruses or parasites on islands.

House Mice were sampled from different areas across the length of Macquarie Island. Some mice surveyed had up to 75 tapeworms in their gut, an indication of the high parasite loads harboured by these mice. Evidence of the water-borne parasite *Giardia* has also been found.

We wish to establish a baseline set of data on the pathogens of House Mice so that we can gauge future change, if this occurs, as a consequence of changes in the density of this invasive species on Macquarie Island. This research can also help to document the potential of House Mice to act as a source of introduction of exotic pathogens to other sub Antarctic and mouse-free environments.

Macquarie Island

The Use of Genetics to Assist Decisions Related to Species Conservation

Dorian Moro

Genetics is more than fruit flies and pea plants. Genetic studies supply conservation scientists and environmental managers with new insights regarding the extent of diversity among the individuals in a population.

To conserve wildlife populations appropriately, scientists must first understand the genetic relationships of different populations of species under study. Once this basic science is understood, wildlife managers can then apply these techniques to preserve biological diversity in these species. This realm of science is now recognised as conservation genetics.

Conservation genetics is an important scientific tool that assists scientists and managers to make decisions related to managing and conserving populations of plants and animals. Without using genetics, we can be left conserving the wrong population, or wasting valuable resources on a population that isn't endangered.

CONSERVATION GENETICS

Arising from the application of conservation genetics research is an understanding of wildlife populations whose taxonomy remains uncertain. An example in Western Australia of a rare native mammal serves to highlight how genetics was useful in deciding upon conservation effort.

CASE STUDY

The Lakeland Downs Short-tailed Mouse (*Leggadina lakedownensis*) is a native rodent inhabiting the arid and semi-arid regions of Australia, but is very rare. One population is known to occur on Thevenard Island in north western Western Australia. Mice on the island are larger in body size than Short-tailed Mice on the adjacent mainland, and differ in body colour. The exotic House Mouse (*Mus domesticus*) became established on Thevenard Island in the late 1980s, and reached plague levels soon afterwards. The threat to the native mice on the island became a concern because House Mice would compete for food and space, and were a potential source of exotic disease.

The conservation significance of the island native mice was in doubt because it was unknown whether they differed from Short-tailed Mice in northern Australia. The uniqueness of this island population would determine how much management effort should be put to their conservation.

Conservation genetics offers one method to help predict the degree of uniqueness of this island population of native mice. There are now techniques, such as the Polymerase Chain

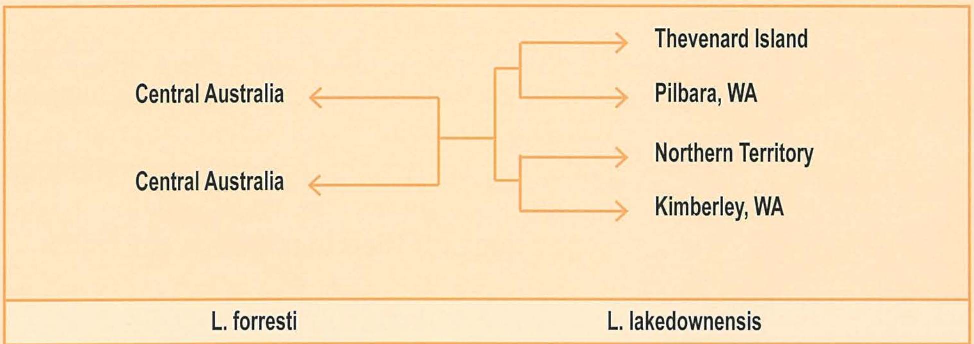


Figure 1
Genetic technology using DNA sequences identified three major groups of native mice in the genus *Leggadina* across Australia

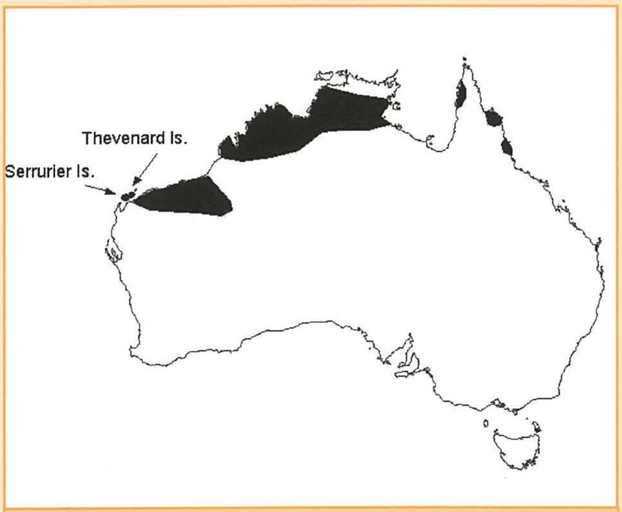


Figure 2
Distribution of *L. lakedownensis*

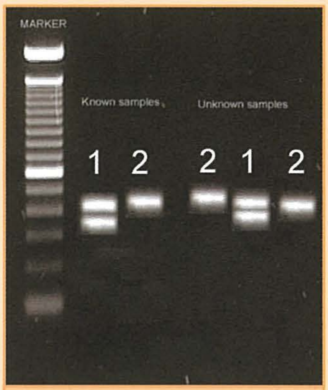


Figure 3
DNA profiling

Reaction, that can amplify a section (or sequence) of a DNA molecule when it is extracted from a tiny amount of tissue such as hair or skin. The sequence of a DNA molecule from one individual is then compared with the same sequence from other individuals within the same population (in this case, native mice from Thevenard Island), and with individuals from populations elsewhere. The differences between sequences will determine how genetically different each population is.

The Thevenard Island population of native mice had an identical genetic makeup, suggesting a single colonisation event. Furthermore, the island population was very genetically similar to those on the adjacent mainland in the Pilbara. It is likely mice from the island originated from those in the Pilbara. When sequences of individuals from the island and Pilbara were compared to those across northern Australia, larger genetic differences were apparent. Furthermore, these differences were as great as those of another species, Forrest's Mouse, suggesting the Lakeland Downs Short-tailed Mouse comprises two conservation groups: those populations from northern Australia, and those from Thevenard Island and the Pilbara.

The use of genetics to help resolve taxonomic anomalies has helped to identify differences between island and mainland populations of these native Short-tailed Mice. Failure to manage the population on Thevenard Island and the Pilbara could result in the loss of a genetically unique population of Short-tailed Mouse in Australia.

Recovery of the Endangered Marsupial Dibbler through Captive Breeding and Translocation

Dorian Moro

The Dibbler, *Parantechinus apicalis*, is a small (40 - 100 g) carnivorous marsupial that is found only in Western Australia. Populations occur in the Fitzgerald River National Park along the south coast of Western Australia, and on Boullanger and Whitlock Islands north of Perth. The total current population is estimated to be fewer than 1000 individuals. It is currently listed under State and Commonwealth legislation as 'Endangered'.

RECOVERY PLANS

One strategy to manage endangered species is to compile a document called a Recovery Plan. Within this plan several management and conservation strategies are comprehensively detailed to explain what research and budget are necessary to support the recovery of the species in question. There is only one national Recovery Plan for a species or ecological community. If there is little information for a species, and management is needed immediately, an Interim Recovery Plan is produced.

An Interim Recovery Plan is now under way to understand more about the biology of the Dibbler (captive breeding, reproductive biology, genetics, translocation, population monitoring), and to manage existing island populations for their long-term conservation.

A COLLABORATIVE EFFORT

The Dibbler Interim Recovery Plan is now the focus of a strong collaboration between the Western Australian Department of Conservation and Land Management, Perth Zoo, The University of Western Australia, and more recently, Edith Cowan University. It is this collaborative effort that has made the Dibbler research a success, because there are many areas of research and management to protect the Dibbler that could not be handled by a single organisation.

CAPTIVE BREEDING

A captive colony of Dibblers was established at Perth Zoo in 1997 with two pairs from Boullanger Island and two from Whitlock Island. Information on the reproductive biology of the

Dibbler is being used to optimise husbandry strategies for future breeding programs.

ISLAND TRANSLOCATION

One of the actions of the Interim Recovery Plan for the Dibbler is to use the progeny of captive colonies to establish a new island population. Together with carefully-managed animal husbandry at the zoo's native species breeding facilities, breeding has been extremely successful, and 88 individuals have been reared for release to Escape Island.

One of the actions for recovery was to establish another Dibbler population elsewhere as a safeguard against a catastrophe befalling either of the existing island populations. House mice (*Mus domesticus)* are common and often in high densities on these islands. Both islands are also easily accessible from the nearest fishing/holiday town of Jurien. This increases the risk of fire, weeds or feral predators being introduced, in addition to trampling on sea bird nests where the Dibblers nest and forage. Escape Island was chosen as a suitable island for Dibblers. It has a similar vegetation to Boullanger and Whitlock Islands, is free of house mice, and has little human visitation.

A total of 26 Dibblers bred in captivity were transported by boat to Escape Island in 1998, and released. Individuals were monitored over the first three weeks by radiotracking, and afterwards by trapping every two-to-four months.

To date, there has been an increase in Dibblers on Escape Island (from 24 captures in February 2000 to 72 in October 2000), though the number changes across the year depending upon births and deaths. Some of the original Dibblers released on the island persist and continue to breed, and second generation young born in 2000 have recruited into the population, bred and weaned their own offspring.

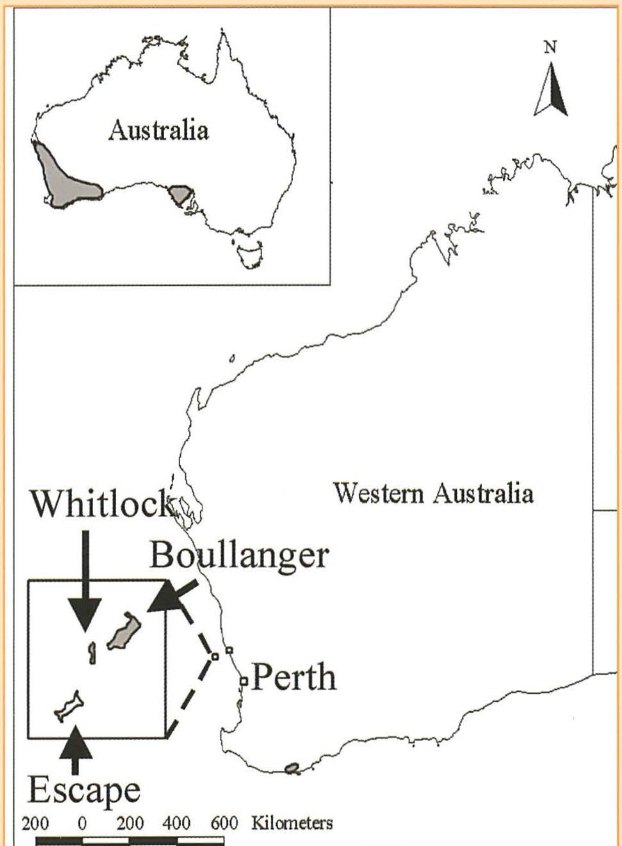


Figure 1
Dibbler distribution

With the combined efforts of members of the Dibbler Recovery Team, the future of the island populations of Dibbler looks promising, a product of good research and management. Research and management for Dibblers can now shift to the south coast populations.

Where do We Get our Seeds? DNA fingerprinting

Peter Hood

INTRODUCTION

An important aspect of revegetation is the source of seed for revegetation of degraded land. It is now generally accepted that local seed is best since local species are more likely to be adapted to the local environment and therefore stand the best chance of long term survival. However in many cases it is difficult for land care groups to obtain seed from the local area; professional seed collectors are often limited in the sites from which they can collect or the plants simply are not available in sufficient numbers for harvest. The question arises therefore, "how far from the restoration site can seed be collected?"

The use of non-local seed for restoration can have severe effects. In some cases it has been noted that plants grown from non-local seed sources exhibited greater mortality and reduced growth rate. Clearly this would have detrimental effects on a restoration program, since replacement plants would be required and plants that survive take longer to reach maturity. This would substantially increase costs. There is therefore a need for land care groups to be able to test potential seed sources.

DNA fingerprinting provides a means by which restorationists can ensure seed is genetically similar to the populations they are endeavoring to restore. By analysing potential sites prior to harvest, the potential of a revegetation program can be increased since plants are more likely to be suited to the translocation site.

Two examples described here show the practicality of such an approach to the restoration of an urban bushland remnant.

CASE STUDIES

The two analyses described below are from plants targeted for revegetation of Bold Park, an urban bushland remnant in Perth, Western Australia. As a consequence of degradation of the area the species are either in low numbers or do not set sufficient seed for harvest. Populations outside the park were tested to give an indication of the genetic diversity of the species along the Swan coastal plain.

ANIGOZANTHOS MANGLESII STUDY

Anigozanthos manglesii occurs commonly across the Swan coastal plain. For the purposes of its revegetation in Bold Park, thousands of seeds had been collected from nearby Kings Park. Prior to the use of this seed it was deemed necessary to genetically test populations from each of the parks and assess their similarity - a third population was selected from Midland as a comparison. As shown in Figure 1, it was found that the genetic diversity of each of the populations is quite different, with minimal overlap. The consequences of using the Kings Park seed in Bold Park are uncertain, however, it most certainly would have affected the genetic integrity of the local population and may also have resulted in plants being less suited to the Bold Park environment.

MESOMELAENA PSEUDOSTYGIA STUDY

Little is known about the germination cues for seed of *M. pseudostygia* and propagation material was required to replenish local populations in Bold Park. For this species, four populations were sampled between Mandurah and Guilderton and compared to the Bold Park individuals. In contrast to *A. manglesii*, this species showed little genetic variation between populations. A consequence of this is that it is likely that propagation material can be used from any of the populations along the coastal plain without affecting the genetic integrity of the Bold Park population.

These results are quite contrasting which is largely a result of the different pollination strategies of the species. *A. manglesii* is bird pollinated and it is not surprising therefore that plants in the same vicinity would be more closely related than those occurring some distance away. On the other hand, *M. pseudostygia* is wind pollinated and so genetic mixing can occur between plants occurring many kilometres apart.

CONCLUSION

It is not intended that this type of analysis be used to the exclusion of all others. Consideration should always be given to parameters such as geology, climate, and community types, since all these can also have an effect on genetic variation and adaptation of populations. However, genetic data can provide a strong tool for differentiating between populations. With increasing importance placed on maintaining areas of natural bushland and restoring environments that have been affected by activities such as urban development, agriculture and mining, land care groups need to maximise their efforts in order to ensure the greatest potential of a site to be self sustaining. DNA fingerprinting can provide an important starting point for this process.

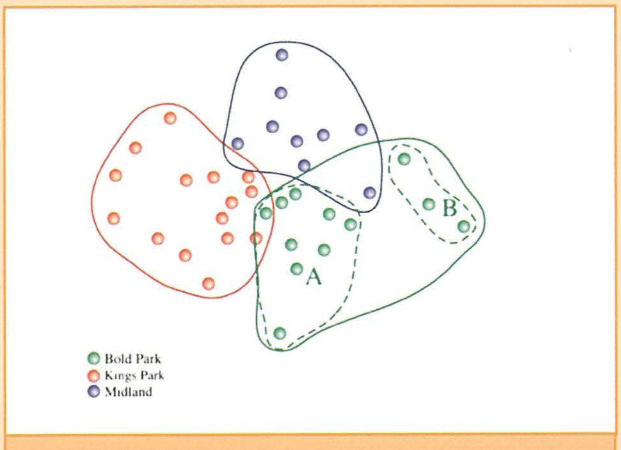


Figure 1
Genetic diversity of different populations of *Anigozanthos manglesii*

Figure 2
Genetic diversity of different populations of *Mesomelaena pseudostygia*

The Decline of the Western Yellow Robin

Jarrad Cousin

Following European settlement of the southwest of Western Australia, widespread clearing of native vegetation has occurred throughout the Swan Coastal Plain and wheatbelt regions to establish towns, roads, industry and farms. Extensive areas of native vegetation east of the Darling Range were cleared for farming, with non-native species of plants and animals introduced. This brought about widespread changes to the native flora and fauna of the south-west.

The wheatbelt region of Western Australia covers a large area of the south-west of the state from Kalbarri in the north-west to Esperance in the south-east. In the wheatbelt there is a variety of land uses dominated by sheep grazing and cereal cropping. As a result of extensive clearing of the original vegetation (130, 000 km^2 or about 93%), up to 95 species of birds within this region have declined in both distribution and abundance.

The remaining 7% of the native vegetation in the wheatbelt is highly fragmented into isolated remnants of varying size and quality, with the

A Western Yellow Robin

Photograph courtesy of Michael Morcombe

majority being small and degraded.

The Western Yellow Robin *(Eopsaltria griseogularis)* is a typical example of a bird that has decreased in distribution and abundance as a result of land clearing. Western Yellow Robins are found in open forests, woodlands, mallee and coastal scrubs of southwestern Australia and south-east South Australia. Much of its distribution falls within the highly disturbed wheatbelt of Western Australia. By understanding the ecology of this species, we may be able to understand the reasons why this bird is rapidly decreasing in abundance and distribution throughout the wheatbelt of Western Australia.

As the Western Yellow Robin is a ground feeding bird, factors that may be contributing to a decrease in their abundance in remaining fragments of native vegetation include the effect of weed invasion and grazing by introduced animals.

The ground is an important resource in the ecology of the Western Yellow Robin as they feed 90% of the time on invertebrates in leaf litter on the ground, which they pounce on from low perches in nearby trees. The ground however, is the part of the environment that is most disturbed by effects associated with land clearing:

1 Sheep and cows compact the ground, which in turn alters the leaf litter layer and affects invertebrates on which robins feed.

2 Sheep and cows excrete within the fragments, which introduces large amounts of nutrients that favour the growth of weeds. Due to the robins' preference for feeding on the leaf litter, an increase in weeds not only alters the ground invertebrates but also reduces the robins' ability to feed efficiently.

3 Sheep and cows also knock off available perching branches that the robins rely on to pounce from.

Western Yellow Robins nest very low in the vegetation, with 54% of nests between 0 and 2 metres above the ground in small saplings and young trees. Grazing limits the ability to nest as tree seedlings are either trodden on or eaten by introduced animals such as rabbits. The availability of nesting sites is thus reduced.

By investigating all aspects of the ecology of threatened birds in Australia, especially the declining woodland birds of wheatbelt regions of Western and Eastern Australia, a more accurate understanding of the habitat requirements of these species can be determined. With this knowledge, guidelines for the conservation of these species can be drafted in order to halt the decline of Australia's birds. Organisations such as the Centre for Ecosystem Management in the School of Natural Sciences at Edith Cowan University play an important role in understanding and resolving problems through postgraduate programs that target conservation-ecology based projects. These projects provide valuable information to land managers and other organisations such as Birds Australia (http://www.birdsaustralia.com.au) which allow guidelines to be drafted to conserve birds throughout human-impacted areas.

Treasure Islands

Gary Luck

When I travel in a plane, I always ask for a window seat. I find the journey much more interesting when I am able to see the landscape below. Cars on busy highways look like ants scurrying along a trail. Their nests are the car parks of shopping malls that dot the suburbs. Outside the city, the plane flies over meandering rivers that resemble droplets of water slinking down a windowpane. Vast, continuous forests stretch across the landscape like carpets for clouds.

Noticeable when flying over the agricultural region of southwestern Australia is the dusty brown of the farmland dotted with patches of green. These patches of green are the remains or remnants of the once extensive woodlands and shrublands that covered much of this region prior to European settlement. Early settlers who called this area their home cleared much of the native vegetation to grow crops and graze sheep. In some districts, greater than 90% of the original vegetation was cleared. From the air, the vegetation remnants resemble islands in a sea of dust. I call these treasure islands because they house much of the rich bounty that is the biological heritage of this region.

Not all islands hold the same amount of treasure. Larger ones generally contain more plants and animals than smaller ones. Those protected from the surrounding sea may be less degraded. Fences around native vegetation islands help to

Photograph courtesy of Dennis Sarson/ Lochman Transparencies keep out the rising tide of non-native plants and animals. This reduces the competition for native species and helps them to survive. Rows of trees that connect one island to another may act as a highway for animals to move between islands. Those not connected to other islands often contain fewer species because many animals find the journey across the open space between islands too difficult. The surrounding sea is a dangerous place if there is little protection from predators or other threats.

Recognising the value of these islands many landowners have undertaken restoration efforts to try to protect the islands' treasure. Revegetation of cleared land, fencing remaining vegetation, and planting rows of trees that connect islands are some of the strategies used by landowners to protect the islands occurring on their property. All of us can help in these activities by joining a local Landcare group or becoming a volunteer with a conservation organisation that is involved in the protection of native vegetation. Working together, we can ensure that the treasure these islands contain is enjoyed by future generations. The next time you travel on a plane sit by the window and watch the landscape below unfold. See if you can spot any treasure islands. Remember that many of the plants and animals we share this planet with rely on these islands for survival. It is our responsibility to make sure these islands do not disappear under the rising sea of human expansion.

Photograph courtesy of Dennis Sarson/Lochman Transparencies

Weeds & Fire: breaking the vicious cycle

Eddie van Etten

In recent times, Perth has grown from a large town of around 400,000 people in the early 1950s to a bustling metropolis with almost 1.4 million people in 2003. Its growth rate has been one of the fastest in the industrialised world. In contrast to other cities, Perth has long been surrounded by large expanses of bushland. As the city has expanded, much of this bushland has been cleared to make way for houses, industry, pine plantations, farms, vineyards, market gardens and parks. Patches of native vegetation are commonly left during the clearing process and the Perth area today literally has hundreds of bushland remnants. Most of these remnants are small; a 1994 study showed there were 631 remnants between 10-100 ha in size, 2062 remnants between 1-10 ha and 974 less than 1 ha in size. As well as being small, many remnants are degraded and most face a range of pressing management problems, not the least of which are the problems faced from recurrent fires and weeds.

We know disturbance of native vegetation and/or soils is often a pre-requisite for weed invasion and proliferation. Fire is an important and regular type of disturbance occurring within woodlands around Perth and experimental burns have confirmed that weed levels can increase following fire. The concern is that increasing weed levels will promote further fire which, in turn, will promote more weeds and so on. This is what is meant by the "fire-weed cycle". Allow the cycle to continue and the danger is that our bushland remnants will become weed dominant as native species decline due to the high fire frequency.

Although we know that fire can enhance weed levels, until a recent Edith Cowan University study, we didn't know much about the other side of the cycle, that is, how weed invasion into a bushland promotes fire. The research, led by Dr Eddie van Etten from the School of Natural Sciences, involved measuring fuel characteristics across a range of remnants with varying degrees of weed cover. The results demonstrated that at sites where weeds were common the load of flammable fuel was up to double that of sites with little weed cover. Not

only that, the fuel bed was more aerated due to the smaller diameter of the fuel particles and less dense packing of the fuel. This is because the dominant weed species were grasses, particularly long-lived tussock grasses such as perennial veldt grass (*Ehrharta calycina*) and African lovegrass (*Eragrostis curvula*). These grasses dry out and become fuel over summer - this creates a different fuel bed to the typical layer of decaying leaf litter found under native plants. Other weeds, such as those belonging to the Iris family (e.g. watsonias, gladiolus, etc), were conspicuous due to their showy flowers but made negligible contribution to the fuel load.

What do these increased and more aerated fuels mean in terms of fires? Using standard fire behaviour models, it was predicted that fire in weed infested bushland would travel at two to three times faster and be two to three times hotter than weed free bushland. In addition, the rapid regeneration of grasses following a fire, from rootstock and seed, see fuel levels re-established within 2-3 years. Without weeds, fuel gradually builds up following a fire in Banksia woodland to reach a peak after about 6 years. The frequency of fire would therefore be expected to increase with weed invasion, particularly as arsonists are increasingly responsible for lighting fires in our remnant bushland. Studies of the fire history of some of our larger remnants have confirmed this, with some burnt areas being reburnt 2-3 years later. This sort of fire frequency eliminates certain native plants which take several years to build up an adequate store of seeds for regeneration. All-in-all, the studies have shown that the fire-weed cycle is real and can cause irreversible damage.

How then can we break this vicious cycle of weeds and fire? Broadly speaking, there are two options. First, we can control weeds to reduce fuel loads to such a level that fires would be less likely to spread and easier to put out. Given the bulk of the problem comes from grasses, herbicides which only kill grasses, if used properly, can be effective without impacting on other species. Unfortunately, other control methods, such as pulling weeds out by hand, result in soil disturbance which seems to promote further weed regeneration. The second approach is to limit fires through such means as fire breaks, public education, deterring arson, and rapid suppression. Fire is not the only type of disturbance which results in weed invasion, so minimising trampling, vehicles, grazing and plant diseases is also critical to keep weeds, and thereby fuel, under control. Much media attention is given each summer to bushfires in and around Perth. What is not reported is that these fires, once started, are promoted by weeds. Weed control is therefore just as vital as fire control.

Vegetation Mapping in Remote Areas

Eddie van Etten

Vegetation maps showing the distribution of different vegetation types are essential tools for those involved in ecological research and environmental planning and management. Dr John Beard, who worked as the Director of the Kings Park & Botanic Gardens, spent 17 years from 1964 mapping the vegetation of Western Australia. He did this, with assistants, by driving along every major road of the State, as well as a fair proportion of minor roads and tracks. From place to place on his travels, he described the vegetation in terms of dominant species and structural features, and marked the location of any changes in vegetation on aerial photographs. From this information, vegetation maps were produced for the whole State at a scale of 1:1,000,000, with more detailed mapping of the south-west. This massive undertaking consumed much time and money, but the results were worthwhile as we now have baseline information to understand, plan and manage our natural environment. For instance, John Beard's maps are used by CALM to identify regions and types of vegetation poorly represented in national parks and other conservation areas.

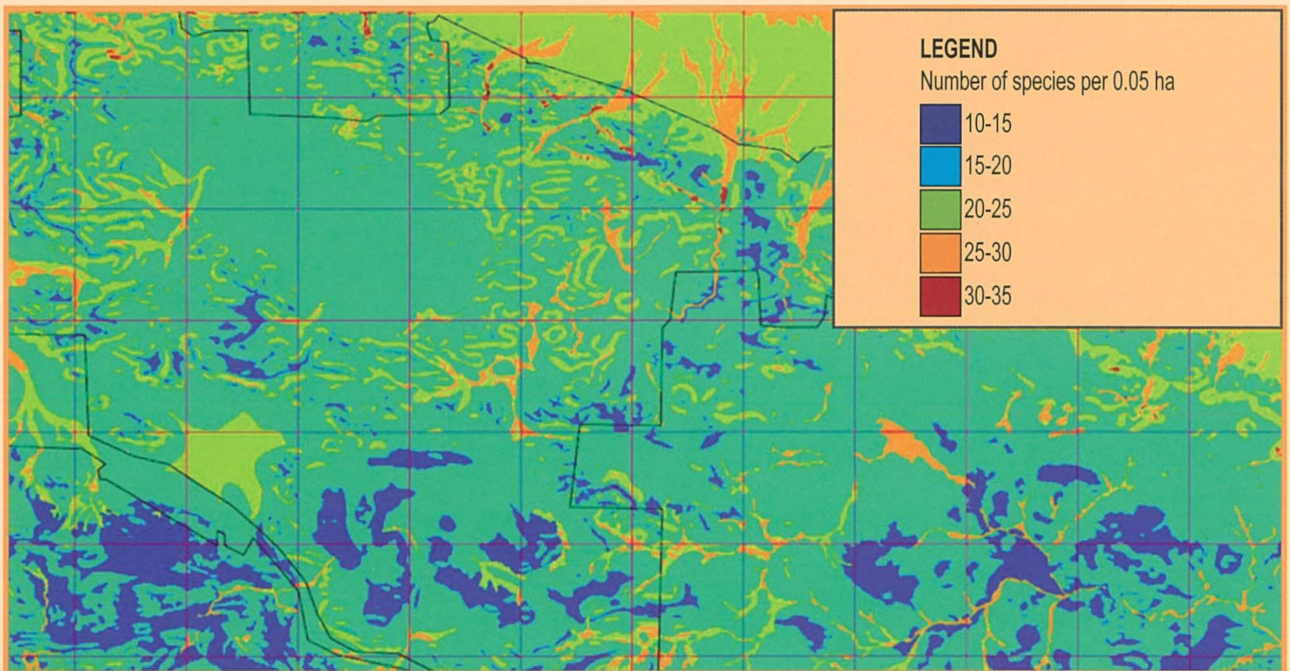


Figure 1
Vegetation mapping for Karijini National Park (10 km grid)

On some occasions, more detailed mapping of vegetation is required. For instance, developers of a mine may need to know vegetation types on their mineral lease; pastoralists might want the same information for their property. This has traditionally involved a similar approach to what John Beard did - ground survey and marking out aerial photographs or topographic maps (at a finer scale, however). This is expensive, time consuming and difficult in remote areas with few tracks and roads, such as much of our desert and semi-arid country in the north of the State.

Researchers at Edith Cowan University's School of Natural Sciences have been trying to find a simpler and quicker approach to map vegetation at a fine scale. Detailed maps of geology and topography are available for the whole State at scales between 1:50,000 to 1:250,000. Could these be used to help predict the distribution of vegetation types? This was attempted for the central Hamersley Ranges in the Pilbara region of WA where a good understanding of the relationship between vegetation and the physical environment had been gained from previous study. The first step in the process was getting the topographic and geological maps in digital form where they could be used within a computer package called a Geographic Information System (GIS). Once in a GIS, the maps could be manipulated and overlaid. The next stage was to establish a relationship (a model) between the vegetation types known for the region and the geological formations and topographic variables like slope, aspect and altitude. This was done in a variety of ways using advanced statistical approaches like generalised linear modelling and decision trees. Next, these models were used within the GIS to predict where vegetation types occur. Although the procedure worked, how accurate are the vegetation maps produced? Accuracy was determined via field testing which demonstrated mixed success. The most important determinant of accuracy was the level of abstraction or, in other words, the number of vegetation types being mapped. It is relatively simple to produce accurate maps of the few major vegetation types. But vegetation can be placed into a hierarchy with major types being subdivided into subtypes and, in turn, each of these subtypes being divided into minor types and so on. The overall accuracy of maps declined the more the vegetation was divided, with generally low (but mixed) success at the finest subdivision (plant community level). This mainly reflects that these communities are no longer differentiated by differences in geology and topography, as well as the fact that the scale of the topography/geology predictor maps were not at a fine enough scale. Despite this limitation, the technique holds much promise as a way to map vegetation where access is difficult. Research is continuing on improving the technique to make the final maps more accurate.

Photograph courtesy of Babs and Bert Wells/Department of Conservation and Land Management

Life Stories

Harry Recher

There is much more to environmental management than conservation and politics. Just knowing how animals and plants live - what they do for a living and what they need in the way of resources - are central to managing the environment. At Edith Cowan University, there is a strong biology program which interacts with the environmental management program so that each is stronger than if they stood alone. Biologists and environmental managers work together in programs of pollution management, animal ecology and behaviour, genetics and conservation biology. Studies of individual species have already been described in the section on Conservation Biology, but here are some examples of the research done on individual species by staff and students on the Joondalup Campus. Some, like the studies of Bobtails, were done at other universities and in other states before the researcher came to ECU, but as with all science, there are no boundaries. Working with colleagues at other universities or those from CSIRO and government advances our understanding of the environment and its needs faster than if each person worked alone. The life history studies illustrated here help show the endless opportunities of a career in the environmental sciences; careers which are exciting and always changing. Careers which know no boundaries, but are so important in creating and keeping a healthy, productive and free world.

Muscle Growth and Regeneration in Crustaceans

Annette Koenders

Crustaceans are an excellent model for studying growth and regeneration. Because crustaceans have a hard shell, growth can occur only by moulting, or shedding the shell. This means they do not grow continuously like many other animals, but growth is cyclic with long periods of relative physiological stability punctuated with short periods of rapid growth at moulting. The mechanisms crustaceans use to regulate and control this process are very interesting, but the process is even more remarkable in many crabs, lobsters and crayfish that have large claws we enjoy eating so much. If you have ever been marroning or yabbying you will know how careful you have to be of their claws; they can give you a nasty nip with them! Large claws cause problems during moulting, because they contain large muscles that have to be withdrawn through a much smaller opening at the base of the limb. In order to facilitate this process, crustaceans reduce the size of the claw muscles just prior to moulting (down to 30%), and regenerate it rapidly afterwards. This ability to control muscle atrophy or degeneration is possibly unique in the animal kingdom. In humans,

muscle degeneration only occurs as a result of lack of use, for example during space flight, or due to a muscle wasting disease. Crustaceans also have the amazing ability to regenerate all of their limbs. Crustaceans will drop a walking leg or a claw to escape a predator or get out of a fight. After some time, a new limb bud appears that elongates and becomes segmented. After several moults, the new limb is indistinguishable from the pristine limb on the other side.

Our research group at Edith Cowan University investigates the processes of muscle growth and regeneration using a variety of techniques, including molecular, biochemical and microscopical techniques. We have confirmed in the yabby that the claw muscle degenerates before moulting, and moreover that some areas of the claw muscle are affected to a greater extent.

We have extended this work to the Bermuda land crab using techniques that demonstrate the expression of a particular gene. The claw muscle of these animals has two populations of muscle fibres. Both contract slowly, but one (S_1) is larger and has less endurance than the other type (S_2). There are many more S_1 than S_2 fibres in the claw muscle of the land crab, and it is known that the S_1 fibres are affected more by premoult atrophy than the S_2 fibres. We hypothesised that the expression of the genes regulating muscle breakdown should be greater in the S_1 fibres.

The gene of interest to us codes for a protein called polyubiquitin. Polyubiquitin is a major component of one of two mechanisms for the breakdown of proteins of tissues in crustaceans and vertebrates alike. For example, polyubiquitin is activated not only in premoult muscle breakdown in crustaceans, but also in muscle wasting diseases in humans. We have demonstrated that the expression of polyubiquitin increases during pre-moult in the claw muscle of the land crab with the inner areas of the muscle degenerating first. Our experiments also support our hypothesis by demonstrating that the expression of polyubiquitin is greater in the larger S_1 fibres than the S_2 fibres.

Our group uses electron microscopy, protein techniques and muscle activation to investigate the regeneration of yabby claw muscle. Some time after the animal has dropped its claw, the new limb bud emerges. At first it is an unsegmented bud containing a tissue that lacks the structure and most of the proteins of muscle. Very soon the limb bud starts to grow and becomes segmented. It then looks like a complete miniature claw, but is non-functional. At this stage muscle structure and the contractile and regulatory proteins of the muscle fibres have already been laid down. In fact, the muscle fibres can contract before the claw is functional! Once the yabby moults, the claw, although small, becomes functional and the muscle tissue is completely regenerated.

The knowledge generated from this research deepens our understanding of deeply interesting and highly significant muscle processes. Ultimately the knowledge we gain may help develop treatments for curing human muscle wasting diseases. Incidental to our investigations, we have discovered a type of muscle in the yabby previously unknown in crustaceans. This is a good example of how little we actually know about these animals, and how important basic knowledge is to our understanding of the biological world.

Mates for Life: pair bonding in the Bobtail Skink

Phillip Mayes

BACKGROUND ON THE BOBTAIL SKINK

The Bobtail Skink, *Tiliqua rugosa*, otherwise known as the Stumpy Tail Lizard, Shingleback Lizard, Pine Cone Lizard or Sleepy Lizard, is found across the southern half of Australia including much of southern Western Australia (see Figure 1). Adults have a length from snout to vent of 25-32 cm and a weight of approximately 300-600 g. The species is viviparous and commonly gives birth to between two and six live young in a single litter with no parental care of juveniles after birth. Birth usually takes place in autumn after five months gestation. Bobtails are known to carry several ectoparasites including several reptile specific tick species. In addition, bobtails are known to harbour microscopic endoparasites including blood protozoans closely related to species responsible for human malaria. These microparasites are spread between lizards by ectoparasites such as the reptile tick species that infest individuals.

PAIR BONDING

An interesting facet of the Bobtail Skinks' behavioural ecology is the formation of pair bonds during the reproductive period. Around the onset of spring each year bobtails form pairs. Pairs consist of a mature male and female and can be seen during the months of September - December each year. Of the two lizards the female assumes the lead position while the male follows her at a distance no greater than approximately 3 m. These pair

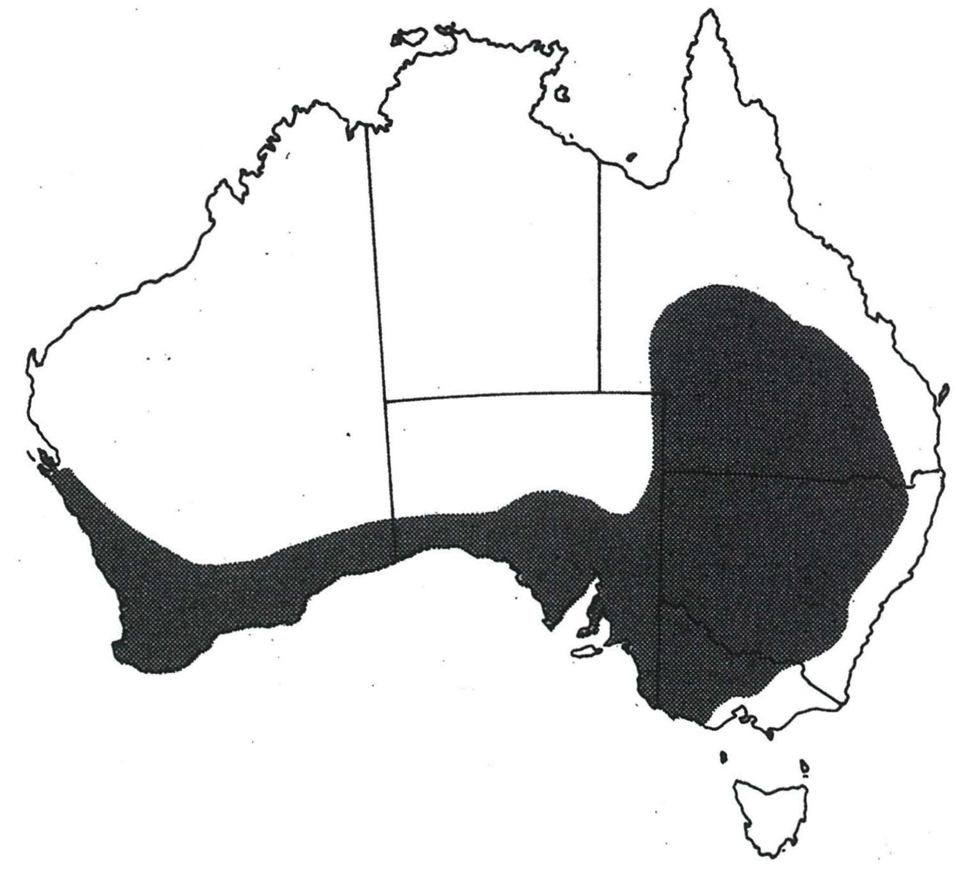


Figure 1
The distribution of *Tiliqua rugosa* within Australia

Adapted from H. G. Cogger, "Reptiles and Amphibians of Australia", Reed

bonds may be formed over consecutive years with animals parting around December, after mating, and reuniting in the following spring. Some pairs have been reported as being together for more than 10 consecutive seasons and it is assumed that such pairs probably associate for life. *T. rugosa* is the only known reptile species reported to engage in such long term monogamy. Many questions concerning the reasons for this monogamy remain unanswered. Current research efforts are looking at: How pairs recognise and relocate each other over consecutive seasons? Why males follow potential mates at times other than when they are reproductively receptive? And finally, what, if any, advantages might this species gain from a monogamous mating system?

The Ecology of the Semi-Aquatic Water Monitor: *Varanus mertensi*

Phillip Mayes

At present I am conducting a two-year field study of Mertens Water Monitor, *Varanus mertensi*, near the township of Kununurra in the Eastern Kimberley, W.A. The study aims to examine various elements of the species' ecology at environmentally different sites. Created riparian sites within the Ord River Irrigation Area (ORIA) are being examined along with natural watercourses in the local area. To complete the study 40 animals have been surgically implanted with temperature sensitive radio-transmitters across all the sites. Radio-tagged animals are then located using radio-tracking techniques throughout the two years of the study. Data from these animals will help to determine aspects of the species' ecology including; reproductive cycle, nest site selection, thermoregulatory behaviour, burrow sites, annual activity cycle, temporal spatial movements and home range size and shape. Regularly throughout the study active radio-tagged animals will also be observed to determine daily activity patterns. Additional non-radio-tagged animals will be captured using either hand noosing or trapping techniques for blood and stomach contents

samples to be taken. These samples will establish both the diet and the reproductive cycle of the species as indicated by temporal fluctuations in hormonal levels.

At the completion of the field study it is envisaged that differences between the ecology and behaviour of monitors residing within created and natural ecosystems will be used to infer if the created riparian ecosystems of the ORIA are fully functioning and self sustaining. This will be indicated by the continual residence of a top of food chain predator, the monitor, within a created ecosystem. If this is to occur, lower levels within the food chain need to be present and fully functional. Alternatively monitors may reside for the long-term outside these systems merely utilizing them opportunistically on various occasions. This may indicate that lower levels of the food chain are not present and/or fully functioning within the system. Hence in this instance monitors may prove to be an informative indicator species when examining the functionality of created riparian ecosystems.

A Family Affair

Gary Luck

Babies need to be taken care of. They need to be fed, kept warm and protected from things that might hurt them. Mum and Dad usually carry out these jobs, but other adults will also help to look after new arrivals. When you were born, you may have had an older brother or sister, or an aunt or uncle help care for you. In humans, looking after babies is often the responsibility of all family members, but did you know that for some animals, raising young is also a family affair?

The Rufous Treecreeper is a bird species that lives in the forests and woodlands of southern Western Australia. An interesting fact about the Treecreeper is that it lives in family groups. These groups are often made up of an older male and female (Dad and Mum) and their sons and daughters. The family group occupies a small area in the woodland for the entire year and sometimes for many years. This area is called a territory or home range.

Like most birds, Treecreepers breed in spring. They build nests in hollows (holes in the branches of trees) and all family members help to build the nest. Once the nest is built, the oldest female (Mum) lays between one to three eggs. She is the only one to sit on the eggs until they hatch. After hatching, there are always hungry nestlings to feed. This is where help from the family becomes important. Mum, Dad and the older brothers and sisters (born the previous breeding season) of the nestlings all help to feed the new born birds while they are still in the nest. This help is important because it ensures that enough food is brought to the nestlings and allows Mum to have a well-earned rest after the exhausting business of egg laying.

What is most interesting about the Rufous Treecreeper is that it is not only the immediate family that helps to feed the nestlings. On some occasions, Treecreepers from neighbouring territories will also help. We are not sure if these birds are related to the nestlings they are feeding (for example, aunts or uncles) or just friendly neighbours. However, their help may be important in ensuring that the young nestlings get sufficient food until they are old enough to leave the nest and begin finding food for themselves.

Babies need care, and the job is made easier if the workload is shared among family members. Just like humans, some animals live in family groups that share the responsibility of raising young. With help from the family, these young soon become adults and are ready to take their turn at baby sitting. Next time one of your family or friends has a new baby to care for, make sure you offer to help in whatever way you can. Remember that for animals like the Rufous Treecreeper, help from family members is very important in successfully raising nestlings and ultimately for the survival of the species.

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